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THE

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PROBLEM OF THE MONTICULIPOROIDEA. I.

THE Monticuliporoidea, comprising the greater part of the so-called Paleozoic Bryozoa, are a comparatively neglected group of fossils, as evidenced in such ways as frequent omission or slight mention of them in lists of fossils or descriptions of faunas. They are not, however, really without great scientific value, but rather their unpopularity may be due to the fact that at present there is a real difficulty for the amateur, the collector, or the geologist in making use of them; this difficulty being magnified, moreover, by a too readily accepted supposition that these fossils are for none but gifted specialists to study. In fact, the specimens themselves are very often excellent, the species quite easy to learn or to identify, and well worthy of consideration as to scientific value in geologic faunas, and the entire group is of peculiar interest to biology.

Aside from the retarding supposition that the Monticuliporoidea are difficult, the present difficulties attending them are these: (1) the interpretation of the animal that built the honeycomb-structured organic remains is still uncertain; (2) the monographs in which they are described want censorship; (3) study of the fossil involves technique more or less. These obstructions are, however, not absolute. It is the aim of this discussion to render them better understood, and hence less feared.

Regarding their interpretation, uncertainty exists to the extent that all Monticuliporoidea may be contested as not true Bryozoa, but Tabulata or Alcyonarian corals, belonging then to a different subkingdom of animals. This uncertainty may be illustrated as to its attendant difficulties by reference to Eastman's[1] *Text-book of Paleontology*, Vol. I, where *Prasopora*, *Neuropora*, and many other genera appear twice, first under Cœlenterata and second under Bryozoa; the first following the text of Zittel, the second the authority of the translator's collaborator, who has taken the liberty to make some revision.

The fact that one cannot assert positively that species of the genus *Prasopora* and other genera were Cœlenterates or were Bryozoons, is due to outward similarity of these two groups and obscurity in the fossils as to class characters. Yet structural details as to minor characters are well preserved, and hence the distinction of species and their grouping into genera is not impracticable here more than in many other groups, since species may be distinguished clearly in fossils as in living organisms without knowledge of phylogenic relation to other classes. Ulrich, who considers them all as Bryozoa, and Nicholson, who treated them as corals, ought nevertheless to present the same determinations as to species, genera, and families. Their failure to agree is not due to that cause. However, the former, in Eastman's translation of Zittel (*op. cit.*), presents as families of Bryozoa (viz., Calloporidæ, etc.) those which, following Nicholson (*vide op. cit.*, pp. 103–105), are given as genera Callopora, etc., of Cœlenterata. Understanding this discrepancy, the handbook is as useful respecting these as other groups, and the fossils are as easily used under its guidance. The student may choose his authority or follow a happy median course.

The lack of censorship in Eastman's *Paleontology*, just mentioned, may serve to argue further need of it in other places. S. A. Miller's catalogue[2] divides the Monticuliporoidea species

[1] Text-book of Paleontology, by KARL A. VON ZITTEL, translated by Charles R. Eastman, 1900.

[2] S. A. MILLER, North American Geology and Paleontology.

between Cœlenterata and Bryozoa. Of other chief works, especially those of Nicholson,[1] we may trust E. O. Ulrich to have criticised them fully. They are conservative and excellent, but inadequate for the study of American fossils without the magnificent recent monographs by E. O. Ulrich[2] to supplement them. The last named, together with the chapter on Bryozoa in Eastman's *Paleontology*, would have offered a complete solution to the student for the study of the fossils and the involved problem of their affinities, if it were not for much obscurity in his definitions. One is compelled to criticise and to interpret anew from the fossils when endeavoring to follow him. In this connection it should be said also that the severe criticism of E. O. Ulrich, by S. A. Miller, *op. cit.*, while touching his works on Paleozoic Bryozoa, does not appear to reach by censorship of the species this group as much or as well as other ones, for the reason, evidently, that his knowledge of them did not permit him. Therefore, while all species are listed as equally valid, some will be found, nevertheless, to have been made upon wholly insufficient evidence and require to be freely eliminated. The most species will again be far easier to identify than their descriptions would lead one to expect. It appears, in short, necessary to admit the value of some earlier criticism[3] of this author, and to expect to find similarities and differences described with acuteness, while fanciful values are frequently attached to them.

Regarding the handling of fossil Monticuliporoidea, one should collect all specimens and in the laboratory select the better preserved ones to begin with. These may be assorted and identified by means of external characters. A common hand lens will suffice to reveal whatever may be not clear to the naked eye. To be sure, the exhaustive study of the material requires the making and use of thin sections when practicable, for often only by that means can the also important internal

[1] H. A. NICHOLSON, On the Structure and Affinities of the Genus Monticulipora 1881.

[2] Geol. Surv. Ill., Rept., Vol. VIII, and Geol. Surv., Minn., Final Rept., Vol. III.

[3] ROMINGER, Amer. Geol., Vol. VI, pp. 103 and 120, 1890.

structure be discovered. The use of thin sections is, however, necessarily limited to special cases. These would be when a new species is in hand and all characters possible should be discovered; or, when a described species is illustrated and described chiefly as to its internal structure, which too frequently is the case; or, when the external characters have been obliterated. Having identified the species and referred it to a genus, etc., by use of all characters, further recognition of specimens of the same can and should, with rare exception, be made to depend on external characters alone. As in studying Brachiopoda, for example, one must know them by external characters, even though examination of internal structures is required to determine affinities of the species.

The advantage of learning to recognize the species, genera, etc., by external characters is in the saving of time, since thousands can be examined in that way, while sectioning limits the labor of one man to at most twenty specimens per day; knowledge of the range and variability of one and many species is made practicable; it serves to direct to best advantage the use of thin sectioning; recognition of species even in the field becomes thereby entirely practicable. Having learned to know a group of species, or the fauna of a locality or of a zone, the specimens may be identified thereafter without the use of sectioning, and the difficulty of technique may be obviated by the geologist.

Thin sections of fossils may be made by the same process as bone or rock sections are ground, which need not be described here. It requires less skill, however, since they should not be ground to absolute thinness. Some simple appliance for measuring the cell dimensions is also needed.

Pains may be saved by attention in collecting, since each bed or zone may have a large proportion of species peculiar to it, and by avoiding mixing fossils of different zones, labor of again assorting is saved.

TREPOSTOMATA

A few selected species may illustrate what is to be looked for in Monticuliporoidea. Beginning with Trepostomata one

then has to do with the most problematic as to affinities of the so-called Paleozoic Bryozoa, *i. e.*, those which most resemble corals, proceeding then to those often supposed to be true Bryozoa, the Cryptostomata. Eastman's manual, *op. cit.*, includes them in the arrangement given below, and in the Order Gymnolæmata, which comprises most Bryozoa and all known fossil ones. Of those five divisions, the last named, Chilostomata, are all undoubtedly Bryozoa, but are not known in the Paleozoic rocks. The first, Cyclostomata, are, with few possible exceptions, all true Bryozoa, but few of them are Paleozoic. The second, third, and fourth comprise the Monticuliporoidea.

1. Cyclostomata (8 families).
2. Families doubtfully referred to Cyclostomata (4 families).
3. Trepostomata (7 families).
4. Cryptostomata (8 families).
5. Chilostomata (13 families).

In that arrangement those of doubtful affinities are embraced between the true Bryozoa. A fairer presentation of the problem may be given thus:

Tabulata (corals)——Trepostomata (?)——Cyclostomata (bryozoa)

Cryptostomata (?)   Chilostomata (bryozoa)

and it is in such association that the Monticuliporoidea should be studied. The group of "Doubtfully referred to Cyclostomata" are Trepostomata.

Beginning with one of the simpler Trepostomata,

Monotrypa magna Ulr. has a skeleton or zoarium one or two inches in diameter, composed of tubes or "cells" which radiate from an approximate center. It is nearly spherical if growing attached on one point, or discoid if on a flat surface, or, again, irregular. The center is the initial or oldest part, and from it one, or practically several, cells arise, and as these extend, others intercalate successively. A specimen divided radially (Pl. A, Fig. 2) shows parallel, approximately equal, cells, each tapering to a point at the inner end. The plan of growth is that of increase in number of cells proportionate to the increase in size of the zoarium. At the surface, the open cell ends are

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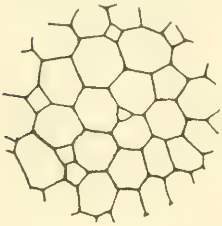
Plate A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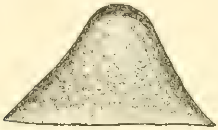
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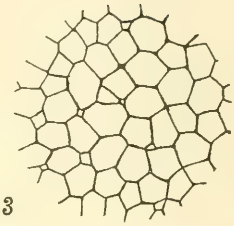
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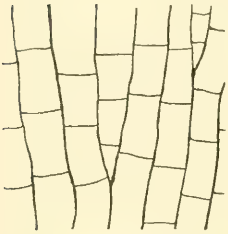
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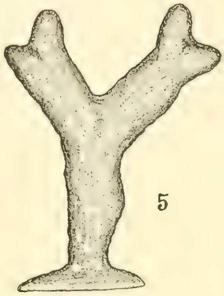
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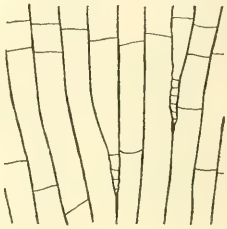
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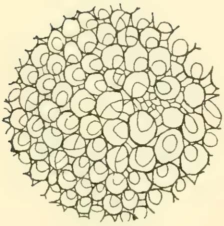
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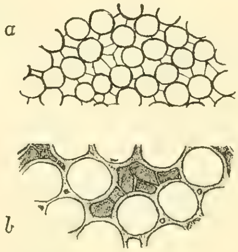

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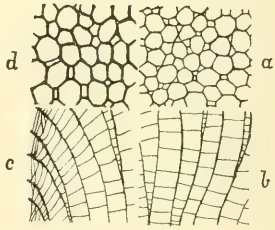

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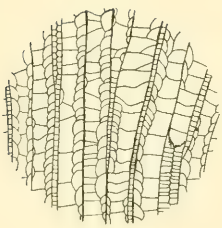
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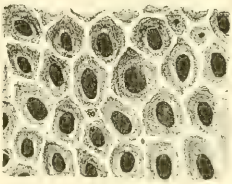
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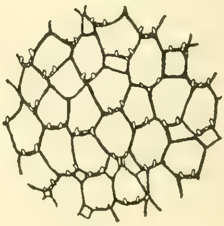
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approximately equal, and, like the cell throughout, are polygonal or hexagonal by reason of contact (Pl. A, Fig. 1). The incipient or expanding parts of cells are seen there as small tri-, or quadrangular openings at the angles between the older, larger cells. Crowding of the cells appears to prevent entire regularity in shape and size of each cell, and the walls are crenulate.

In speaking of cell one includes for each the half of the bounding wall, although the walls originally are dense, amalgamated, calcareous structures, not double further than that they were built not only by increment upon their margins, but also on the two surfaces. Theoretically there is a boundary plane or division between cells midway in the wall. They frequently split midway in the wall when fractured. The walls in this species are thin and show little or none of their growth structure. At a slight depth within each cell the last growth increment or layer crosses the cell opening and forms a transverse partition or false bottom, the so-called tabula. Tabulæ occur successively in all cells more or less regularly, but not corresponding in neighboring cells. They are a little more numerous in the incipient part of each cell. The wall edge of one cell cannot extend above those of its neighbors, from which it never separates.

The zoarium corresponds in structure to the following supposed manner of growth: It was covered when alive by numerous equal sized zooids which coalesced laterally, the lower part of each, however, extending into and secreting the walls forming the cell or zoœcium. Young zooids arose among them and, growing, extended relatively downward, building a new cell; the increase in number of zooids and, respectively, cells, being compensated by a necessary growth in radial length of cell wall to increase the surface of the inhabited zoarium. The tabulæ indicate successive planes where the bottom of the zooid rested between periods of necessitated self-extraction from the ever too long cell.

E. O. Ulrich assumes that the cells are "Zoœcia, directly superimposed upon one another so as to form long tubes

intersected by straight or curved partitions . . . ." That interpretation appears in form of a definition only; and not knowing how it could be applied to the initial part of cells, respectively young zooids, which then must be supposed to have required several generations to reach maturity, the other interpretation will be kept for the present, viz., that each cell is one zoœcium.

Variation in such species as this one would consist in the zoarium growing in one part more than another for some cause, being one-sided; or it is discoid because of perigene growth, *i. e.*, the cell increase is greatest around the margin; or, again, it is acrogene. The surface upon which it grew affected its growth also. The cells remain nearly uniformly large, the number of young cells seen at the surface varying. The cell walls appear uniformly thin.

Those characters are seen at the surface or in transverse thin section. Longitudinal section would show the tabulæ to vary, being fewest where cell length most rapidly increased, and the slightly differing rates of expansion of the cell initial. The latter character can also be estimated at the surface. Other species near to this one are in various ways more complex. Thus,

Diplotrypa limitaris Ulr. has nearly the same manner of growth as *Monotrypa magna*, differing in smaller size of cells and shapes of their apertures at the surface (Pl. A, Fig. 3). Here the number of immature cells nearly equals that of the mature ones. Longitudinal section shows that the young or initial part of each cell is long, slowly expanding, or even for some length not increasing, then quite quickly becoming full-sized, mature (see Fig. 4). The tabulæ are closer in these initial parts, technically called *mesopores*. The plan of growth thus differs from that of *Monotrypa magna* in that in the latter new cells appeared only as fast or numerous as they were to develop into mature cells. In *Diplotrypa* the new cells appear too rapidly, so to speak, and await their turn to expand into full size; hence the more

numerous small cells, mesopores, among the full-sized autocells at the surface. The calycal or open part of the cell is shallower in small cells or mesopores than in the larger ones, and that is true in all Monticuliporoidea. Also the autocells crowd the mesopores so that the former tend to become circular at the expense of the latter.

Callopora multitabulata Ulr. began like a *Mesotrypa*, but acrogene growth obtained (Pl. A, Fig. 5), the zoarium being long, cylindrical, branched, arising from a basal discoid expansion. The tips, or apices, are only then like small *Mesotrypa*. The greatest growth of zoarium and cell increase was at the zoarial ends, and there the cells increase centrally, so that some were being crowded away and turned their apertures to the peripheral surface, *i. e.*, away from the axis of growth (Pl. A, Fig. 6, *c*). The grown zoarium is thus composed of two regions, the axial or "immature" region of vertical cell part (Fig. 6, *b*, *a*), and the peripheral or "mature" of laterally directed cell (Fig. 6, *c*, *d*). In the peripheral region the cells grew slower in length, have thicker walls and more numerous tabulæ, and there are more mesopore cells. The apical parts also become finally slow-growing, thick-walled, with many tabulæ and many mesopores, and it is evident that the zoarium grew rapidly to nearly full size; then a retarded or "mature" growth followed. Renewed rapid zoarial growth and a second retardation stage often occurs, wherefore the terms immature and mature regions are presumptious terms. Peripheral and axial regions are better, since they leave the degree of maturity to be described. Upon the thick-walled peripheral and apical part there occur at nearly regular intervals elevations called monticules. These are occupied by a small group of larger-sized, cells with mesopores or young cells. On the thin-walled or growing apex, and hence in the axial region, these are represented by a group of likewise slightly large-sized cells, with abundant mesopores, resembling less distinct cell groups occurring in *Monotrypa*, etc. Nicholson proved monticules to be points of greater cell increase, and while

young cells may appear at any cell angle, their increase is greatest in the monticules or cell groups. In renewed rapid growth the peripheral monticules tend to develop into branches of the zoarium, but of course all could not. Thus monticules are similar to zoarial branches, but are not branches normally. Branching of the zoarium is due to double region of acrogene growth only.

The tabulæ of *Callopora multitabulata* are thin, and the last one is near the cell aperture, and is said to be perforated at the center (*vide* Eastman, *op. cit.*, *f*, 456 *d*). They are nearly always solid. Right here is the chief supposed basis for the interpretation of Trepostomata as Bryozoa. According to E. O. Ulrich's definition (p. 271, Eastman), each tabula was the perforated top of one zoœcium and solid bottom of the next. In fact, the thickened walls here show only that the growth increments lengthening the wall continue on either side downward, thickening the wall, and thence as tabulæ across the cell opening. Further is not seen. Perforate last tabulæ may be incomplete ones.

The characters for distinction of the species are, therefore, mostly visible on the exterior; the shape of zoarium and its branches, shape, size, and shallow depth of the cells, characters of the monticules, the number, size, and shape of mesopores, and thickness of the wall. All these characters vary, and the variation of all should be noted in learning the species. Extremes may be associated on parts of the same specimen.

Prasopora simulatrix Ulr. grew upon some solid surface, at first lens-shaped, later conical (Pl. A, Fig 7), hemispherical, or irregular, expressing slight tendency to acrogene growth, united with moderate established perigene. A short finger-shaped or a branched sporadic acrogene growth occurs sometimes, and this usually at the center. If the colony died off in part, the remaining part then developed, overspreading the old. Even a symmetrical zoarium could develop from the irregular fragment of another. The cells radiate from the flat or concave lower

side to the convex upper one, the lower side being covered, if well preserved, by a thin "epitheca" or coating produced by no one zooid, but by the cortex uniting all. The growth of the epitheca was, of course, marginal. At this margin, close on the epitheca, there was rapid budding of young cells, some of which became quickly full-sized; others became mesopores. At the periphery the cells open obliquely to the zoarial surface. Above it all apertures are more direct.

The number of mesopores in this species (Pl. A, Fig. 8) is so far greater than that of the autocells that relatively few of them can become autocells. They are fewest proportionally in maturer zoaria, and appear to be homologous with those of *Diplotrypa*, only smaller, longer, and, so to say, more permanently mesopores. The numerous small, angular, or impressed mesopores, with shallow openings or calycals, surround the rounded apertures of the thick-walled autocells, making an easily recognized figure at the surface. At intervals occur clusters of cells larger than the average, with more numerous mesopores between them, and thicker walls. They form low monticules, or on weathered specimens high ones. They are areas of rapid cell increase.

The mesopores have numerous transverse tabulæ (Pl. A, Fig. 9). Those of the autocells are numerically proportional, considering the cells' size, but they curve obliquely across, or oftenest form cystiphrams, *i. e.*, the tabulæ in the most regular instances are narrowly beaker-shaped, and are arranged in the cell as nested equal-sized beakers could be in a tube. The flat bottoms have been called diaphragms or tabulæ, the sides cystiphrams. Often the cystiphram extends only partly around the cell, and partly the same lamina is incorporated with the cell wall. Cystiphrams appear to indicate that the zooid body withdrew simultaneously, or nearly so, from the calycal bottom and side, or sides, near the bottom.

The cell wall margins here were not all straight since, *acanthopores* occur. These are minute wart-like structures or thickenings on the cell wall margins, especially at angles, and were

presumably built into corresponding invaginations of the living cortex. They are not cells or pores, but have been supposed to be, hence the name. They are inconspicuous in this species or even wanting, and will be discussed later.

Characters sufficient for the determination are upon the exterior in this as in related species. The peculiar cell pattern can be readily distinguished from structurally very similar ones. The variability in cells, acanthopores, etc., will however be found greater, and there are fewer true species of the genus than recorded. Other species of *Prasopora* have more perigene growth, or, again, acrogene ones are the *Monticulapora*.

Homotrypa minnesotensis Ulr. has long, round, slowly-branching zoarium, with many specific marks as to cells, monticules, etc. Fossil stems are in part or entirely hollow, because the axial region has very thin crenulous walls without tabulæ, hence the sea water could enter and eat away the walls, leaving, if anything, the thicker-walled tabulate peripheral region. The peripheral cell has cystiphrams similar to *Prasopora*.

Batostoma fertile Ulr. consists of large, flattened, or round, somewhat irregularly branching acrogene parts, arising from a large basal expansion of irregular perigene growth. A single basal may support more than one or, again, no acrogene part; but as in *Callopora* a thick walled maturity follows the thin walled, immature stage. Thus the characters of peripheral and axial regions are evident when there is even no acrogene growth. Omitting some details, the peripheral region has thick walls on which are well-developed spines, acanthopores. Mesopores may be very few or, again, very numerous on parts of the same specimen (Pl. A, Fig. 10, *a*, *b*). They are "closed," *i.e.*, their tabulæ built close up to the apertural margin, by which the mesopores, being shallow or confluent, look like closed interspaces merely between the rounded autocells. The cell clusters, which are in place of monticules, have *maculæ*, *i. e.*, clusters of mesopores at their center. The young cells of the axial region

expand quickly, and are scarcely tabulated and very unlike mesopores of the peripheral region, and they are not called mesopores. The mesopores of the axial region are not immature cells but permanently retarded ones.

With this species is conveniently compared *B.* (*Hemiphragma*) *ottawaense* Foord, in which the thin-walled axial and thick-walled peripheral regions are sharply defined, as seen in thin section or in fractured specimens. At the stage when peripheral region is just begun one sees characters very like *B. fertile*, but later the walls thicken more, the mesopores are obscured, closed, or filled, while the maculose-looking monticules show strongly diverging cells, indicating slow growth in cell length compared to width. Acanthopores developed. The tabulæ are peculiar, being often thickened and incomplete, hemiphragms, in the peripheral region. The whole wall in the fossil is corneus looking. They show the result of a decrease probably of calcareous constituent.

Eridotrypa mutabilis Ulr. includes rather small, long, branched, acrogene zoarial parts in which, as seen in cross fracture or section, the cells are larger in the axial region than in the peripheral. The cells turn very slowly in the peripheral region, so that the apertures are oblique to the surface and drawn out anteriorly. Then, as the cells become more direct, the walls increase steadily in thickness, and in very "old" specimens distinctly cup-shaped calycals form (Pl. A, Fig. 11). The thickened wall permits analysis into the bounding edge with its projection downwards, as dividing lamina, and the calycal slope and the main wall below it (*cf.* Fig. 1, *h*, *p.* 21).

Anoloticliia impolita Ulr. has irregular large acrogene zoaria, with large cells of quadrangular rather than polygonal outline, and with few mesopores, reminding of *Monotrypa magna* (Pl. A, Fig. 12). The axial and peripheral regions are scarcely distinguished. In the latter stage there are, however, *lunaria* developed. The lunarium occurs in the posterior side of a full-sized cell as a narrow, distended part of the cell. The term lunarium has been applied rather to the lunarial wall, which is narrowly arcuate or crescentic. Where the lunarial and common cell walls join, in

this species, the angles project inwards, as if produced. Moreover the lunarial wall is a little elevated at the surface, making it appear as a distinct wall, but it is really part of the wall deflected and extended. I have searched in vain for the symmetrical crescent that has been figured as the lunarial structure of this species. It appears really to be somewhat irregular, bearing tooth-like points, the downward projections of which appear lucid in thin sections, and are the "vertical, closely-tabulated tubes" described by the author of the genus and species. These same lucid spots in sections crossing calcite-filled cells are very deceptive, appearing like pores. In clay-filled cells they appear clearly as parts of the wall. They interrupt the median wall and confuse in color with the outer laminæ, these lighter parts being also of the same color as calcite infiltration; hence the deception in the fossil.

Fistulipora carbonaria Ulr. is of common, massive growth. Its autocells are rounded, with here and there one having a slight distension, as if a lunarium was developed with minimum distinctness. The autocells are separated by angular, large mesopores in single series, except in the clusters or maculæ, where they are more numerous. The walls around autocells are thick, while those between mesopores are very thin, low, and scarcely above the last tabulæ; hence the appearance is that of isolated autocells with raised "peritreme." Longitudinal section shows the mesopores to have arched, numerous tabulæ, appearing thus as vesiculose filling, or "cœnenchyma" between the autocells. New autocells arise abruptly, displacing one or more mesopores in the midst of mesopores, *i. e.*, "cœnenchymal gemmation."

Stellipora antheloidea Hall encrusts shells, etc., growing laminar or massive, a centimeter thick. The surface is crowded with stellate monticules about 2.5^{mm} wide, each consisting of a central, six to twelve-rayed, depressed, quite smooth, macula, and around this, between its rays, an equal number of ridges which are highest at the inner end and slope outward to the interspace. Sometimes additional ridges occur midway between the outer ends of the primary ones. The maculose

area, as proved by sections, is composed of large, angular mesopores, and the ridges exclusively of rounded autocells, these tending to arrange in two rows, with the walls between the rows a little raised and straightened. The space between monticules is small and occupied by mesopores around a few single autocells, and groups of two, three, four, etc., cells or incipient ridges. In longitudinal sections the close tabulæ only distinguish the mesopores at first, but they soon become vesiculose.

This description is taken from specimens from the "Trenton shales" of the Northwest. The species is very rare as compared to the acrogene ones generally called *Constellaria.*

DISCUSSION OF TREPOSTOMATA

A few species suffice to illustrate the general characters of Trepostomata, and the further detail may be explained by them. In this manner of beginning with a few representative species, proceeding thence to the study of the several characters recurring in the whole group, the perplexing taxonomic definitions may be obviated.

The growth habit or zoarial form is fairly constant in the species, but very various beyond that taxonomic limit. The approximately hemispheric zoarium, with its cells radiating and multiplying with growth from an initial point, may be taken as the central or composite or primitive type. Next, species with an established tendency to grow fastest around the base develop the flattened massive type. Others, more perigene in degrees, connect with the laminate or encrusting, in which perigene growth is near its practicable extreme.

On the other hand, the hemispheric form, by increased acrogene growth tendency, becomes the digitate, and finally dendroid branched. But, as a rule, the acrogene zoarium has a perigene basal expansion, and every degree of form might be pointed out from the conical (Pl. A, Fig. 7), in which moderate acrogene and perigene combine, to the strongly acrogene form, with more or less extremely perigene basal (Fig. 5). As to the basal expansion, it may be massive, laminate to encrusting. It

may in some species support two or more acrogene growths, and in just these cases also the acrogene part may be small or wanting, arguing that the basal expansion might have been the origin of some strictly perigene species, the acrogene part being wholly suppressed. The laminate form may have again become massive. Finally, an acrogene growth may be round, compressed, flattened, frond-shaped, or bifoliate. In short, the series between zoarial forms is very complete, and genetic relationship between the most extreme forms may be presumed. The lines of evolutionary development have never been traced, however, and they evidently cross or parallel in a confusing manner; hence this character is of taxonomic use in species chiefly.

The different zoarial forms result not from changed shape and size of the component cells, as one can readily observe in similar zoaria of extremely different cells, but, as seen firstly in variations of a species, it results from increase of cells, the region of greatest cell increase being that of greatest zoarial growth, and inversely. The change of zoarial form, nevertheless, must be made to explain the change of cell as seen in different regions in the same species. Thus, in the acrogene growth, where the cells are turned from the axis of rapid growth to the peripheral slow growth region, it changes markedly, becoming thick walled, closer tabulated, etc. (Pl. A, Fig. 6, *c*). Noticing that the cell apertures do not spring apart under any circumstances, and presuming that this is because the respective zooids were bound together by a cortex, it can be understood how the same cell can be different in two parts, and why there are certain differences in cells. Thus, the tip of an acrogene zoarium, like a hemispheric or massive zoarium, has the cells subparallel, lengthening as new cells develop, so that the surface or circumference widens and the radius or cell-length increases proportionately. But as a cell turns into the peripheral region it comes into a zone of more restricted circumference and radial lengthening; hence the cell is shorter, thicker-walled, and closer-tabulated. Moreover, the cell-increase lessens to some degree, which further restricts the circumference and radius with added effect. In the

latter way the apex of branches often retarded building thick-walled and close-tabulated cells, and sometimes the basal expansions did likewise; and it is evident then that a kind of zoarial maturity exists, simulating if not derived from the "peripheral" stage. Further, specimens in which a mature stage has developed at the apex may renew axial growth and cell characters, a second maturity following, by which it would seem that environmental causes have had to do with the time of maturity.

In a specimen of *Eridotrypa mutabilis* Ulr. at hand, a fortuitous branch has arisen from the mature region instead of the axial, and consequently a cell can be traced as axial, peripheral, axial, and peripheral again. Injured or broken zoarial parts are commonly renewed by thin (axial) cell growth, even in the peripheral region, a stolon-like expansion first overspreading the dead area. In perigene growth also the young cells arising at the margin are at first more prostrate than later, giving rise to a basal stolonal region, and in thin, laminar, or encrusting forms it is very distinct. In these cases the stolonal has been said to be probably the homologue of the axial immature region of dendroid zoaria. The stolonal and immature regions in these may coincide, but it is wrong to assume that they do in other and all cases. The stolonal part need not be considered as coördinate with the developmental peripheral and axial regions. It seems, in fact, unnecessary to attach any genetic significance to the stolonal region further than that it is incidental to perigene growth.

In a given species one specimen larger than the other may be so either from more vigorous growth, as seen in larger axial or immature region, or from longer continued growth, as seen in thicker peripheral or mature region.

Cell increase is, as a rule, intermural, *i. e.*, young cells begin as small, round pits in the wall at the angle between three or more older cells. The reproduction or budding of zooids doubtless took place in the cortex above the zoarial skeleton, and only later the young zoöid comes to build a cell, which, however, from its initial, has its own wall, *i. e.*, wall-half. The young cell

becomes triangular, quadrangular, etc., in proportion as it grows large enough to neighbor on three or more cells. Young cells have shallower calycals and are generally closer-tabulated, but proportionate to their size, as compared to mature ones. The number of young cells in proportion to large ones affects the cell pattern at the surface. This is especially notable when the simplest case of rapid, direct, continuous expansion of young cells is contrasted with that where "mesopores" are numerous (Plate A, Figs. 1 and 10).

Mesopores are said to be present if the young cells when about half-grown in diameter, retard or cease their expansion, but, of course, continuing length growth. If the mesopore stage of cell is short, few mesopores, if long, many mesopores, are present. They may outnumber the autocells so greatly that a small proportion only could become autocells. They may be more numerous in the peripheral, mature, or retarded cell growth region. Again, as in *Prasopora simulatrix* many mesopores remain such while other newer ones develop to autocells. Yet, apparently any mesopore may finally become autocell. They are, however, something more than retarded young cells, in case like *Stellipora* (*Constellaria*), where the angular mesopores are rather larger instead of smaller than the rounded autocells.

The more distinct the mesopore development the more subordinate they appear to become. The autocells are angular from contact with each other or young cells, but rounded when crowding mesopores, the latter alone remaining angular. Also the mesopores become shallow, the tabulæ developing close to the wall margin forming "closed" mesopores, or they even filled solid with superimposed tabulæ; or the tabulæ overlap the walls, forming "vesiculose" structure. Autocells arise, displacing several mesopores at once, "cœnenchymal gemmation," in some species with vesiculose or even regular mesopores.

Monticules, as Nicholson pointed out, are rapid cell increase areas. In simplest cases they appear at the surface as mere small elevations or more or less elevated clusters of slightly larger sized cells, among which young cells are seen except

rarely in a growth retardation stage. A few young cells or mesopores are present, or many mesopores, or again aggregated mesopores between the cells are found in some species, or exclusively mesopores form maculæ or large aggregates in other species, with or without surrounding major-sized autocells. The elevated clusters are the typical *monticules*. The extreme degree of elevation is expressed by the name monticule. Maculose ones or "maculæ" are nearer plane or slightly depressed. Exceptionally a typical monticule may extend like a ramulet, in which case it is probably to be considered as such,—a fortuitous acrogene growth having sprung from the area of one monticule as it might also have from that of several.

The monticules are distributed on the zoarial surface more or less regularly, new monticules arising from the widening intervals, and never, apparently, one monticule from another. The function of the zooids that built the major autocells is unknown if it was different from that of others. The only discernible peculiarity of the monticules to which a special function could be assigned is their more rapid reproduction or cell increase than the interspaces. In this respect they resemble the acrogene growths or the axial region, and when very prominent they might suggest an origin as retarded branches, but no unquestionable transitional forms to these are known to me. They differ from branches in their size and in relation to the zoarium as a whole; for, if monticules produce the more new cells, their interspaces produce the less, the zoarium being unchanged; while, on the contrary, growth of branches comprises essentially the zoarial growth as well as the maximum increase of cells.

The surface pattern, as shown, is very diverse. The average size of cells in a species is quite constant, but in different species differs several diameters. The form of aperture, quadrangular, polygonal, to rounded; the relative size and numbers of young cells and mesopores; the monticules and maculæ of varied style; all these form conspicuous essential characters by which species can be recognized. The calycals, too, are deep

or shallow, relatively, in different species. The autocell walls, which are thin and then more or less thickened, give respectively polygonal or rounded calycals, since the thickening is greatest at the cell angles. A beveled wall edge or impressed rim around the cell aperture gives it in many a saucer-shape, especially when the walls are very thick (Plate A, Fig. 11).

Acanthopores or warts may be present on the walls, usually at cell angles. A lunarium, when present, gives the cells another peculiarity. The lunarial wall and the acanthopores are, however, mural modifications, and will be explained in that connection later.

Thin section is quite necessary to bring out the wall's structure. The walls are dense. If thin they may show no differentiation; yet, if a specimen split, the cleavage may pass longitudinally and so as to leave part of the wall attached to each stone core, which fact has been taken to indicate that the wall is always structurally double! Presumably the wall is built double always, *i. e.*, the increment on the margin is continued within every calycal, the wall being thus double with a median, third part, which is, however, not known to be double. A thickened wall tends to show greater differentiation, both in structure and composition, than a thin one. The median wall may appear either distinct or not, and correspondingly the striping parallel to the wall's surface when seen, showing the laminæ of growth, is either interrupted by the median wall or more or less distinctly crosses continuously from one side wall to the other.

To explain the structural aspect of acanthopores in thin sections, the following analysis may serve. A distinctly double wall shows the median wall as a line in transverse section (Fig. 1, *a*) and when the wall edge is scalloped (Fig. *b*) the median line appears interrupted in section (Fig. *c*), corrresponding to the angles. A rounded wart (Fig. *d*) would produce a similar effect (Fig. *e*); or, if very distinct, as in Fig. *f*. When once begun, the wart may have its own growth, so to say, independent of the wall thickness (Fig. *g*), becoming so large as to appear

to have displaced a young cell or mesopore. Such a large acanthopore inflects the cell wall, forming a vertical rib or pseudoseptum as a rule. No doubt the acanthopore end, or wart on the wall, extended to fill an invagination in the web or cortex which bound the zooids to which the cells belonged. Explanation of the cause of such invagination need not be attempted here. But it may be added that the walls were evidently built by surface secretion, and that the growth of a projecting wart would be accumulative as compared to a plane surface, other things being equal. This may explain why acanthopores are

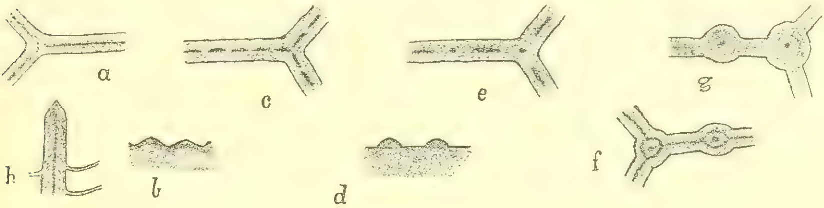

Fig. 1.

often so independently large. A scalloped or saw-edged wall would not develop so. The transverse of a wall would, however, if the zooids and cortex did not draw upwards fast enough to prevent it. Thus a wart thickens in two dimensions to the wall's one. Since, however, the wart is on the wall, it receives below the wall thickness also, and hence acanthopores might well be four or more times the thickness of the wall from result of secretion alone. In fact, it is necessary to explain why the walls, etc., can be very thin, which is evidently because the zooids drew forward rapidly.

It is fair to presume that structural differentiation of the wall may be accompanied by difference in composition; and that may explain why the elevated lunarial wall may be different colored and textured than the main wall; or, again, lucid vertical lines or "lunarial tubuli" only are different, these being the vertical extensions of tooth-like elevations on the lunarial wall margin. Acanthopores show similar differences. Such structures might be mistaken for mural pores in thin sections. Mural pores do not occur.

Tabulæ perhaps need no special mention; their character as the successive bottoms of the calycals is entirely evident (Plate A, Fig. 2, and Fig. 1, *h*, p. 21). In structure, if any be seen, they are one-sided. E. O. Ulrich has observed the very rare occurrence of perforation or circular opening in the last tabula, which he interprets to prove that all other tabulæ are double, comprising the amalgamated cover of one zoœcium and bottom of a next superimposed zoœcium. In absence of any substantiating evidence it is better to take the most direct explanation, which would be that the observed perforated tabulæ were left incomplete by the death of the colony. Indeed, in *Hemiphragma*, the tabulæ of the cells in the peripheral region are all left incomplete or were imperfect as to calcareous structure. The surfaces of tabulæ are sometimes papillated, and these again, like the acanthopores, simulate perforations in the fossilized specimen.

As a rule, neighboring cells do not have corresponding tabulæ, either in position or number. In any species or individual they are approximately regular in position and numbers, but never quite so. In different species the number ranges in extremes from none, as seen in the axial region of some species, to very many in others, or even to a compacted papillose mass filling the cells, or especially the mesopores in some thick-walled forms. There is no unit form and size of loculus assignable, which argues very strongly against any theory that the successive loculi represent superimposed zoœcia. The clearer interpretation is that each cell was built by one zooid. Tabulæ are, as a rule, very thin; and tabulæ wanting and tabulæ thickened are opposite degrees. Individual variation and specific difference in number and thickness of tabulæ may be ascribed to difference of growth and to secretion of substance. Difference in form, such as the cystiphrams (*Prasopora*), are ascribable to shape and size of the zooids' base; and vesiculose mesopores, to shallow or closed calycals from short zooids, and to their shifting, possibly, also.

AFFINITIES OF TREPOSTOMATA

Regarding the affinities of the Monticuliporoidea as a whole, the evidence uniting these to the Bryozoa on the one side, and to Tabulata or Alcyonarian corals on the other, does not lead to a compromise conclusion that they really were related to both as an intermediate or connecting link, because, as will be seen, the interpretation of the zoarium necessary to unite them with the one is discordant to that necessary to unite them with the other; and because of evidence to the contrary from the embryology of living Bryozoons and corals. Discussion is therefore confined to the question whether the extinct Monticuliporoidea are Bryozoa or Cœlenterata.

In relation to Bryozoa, the problem begins with the Trepostomata section, some or all of which have been variously and doubtfully referred to Cyclostomata; and this order of Bryozoa is extant. The reference involves comparison with the supposed Cyclostomatous genera *Neuropora* and *Heteropora*, of which we are yet uncertain. Gregory[1] refers these as typical Trepostomata, not Cyclostomata. The question rests mainly upon the fossil and recent *Heteropora* which Nicholson[2] has thoroughly discussed and which, as it appears, simulates Trepostomata, but has many transverse mural pores and other differences. Trepostomata must therefore be proved to be Bryozoa and *Heteropora* likewise to belong to Trepostomata, before they can be united with assurance. Gregory's reference needs proof and affords no evidence, but expresses well perhaps that we are uncertain of all. Passing to the comparison of Trepostomata with undoubted Bryozoa, this requires knowledge of the extinct Cryptostomata, which must in turn be compared with Bryozoa; and discussion of that part of the problem will therefore be deferred to the section on Cryptostomata.

In relation to Tabulata or Alcyonarian corals, Trepostomata may be compared immediately. In the first place, such forms as *Monotrypa* compare with *Chætetes*, a massive zoarium of small,

[1] Catalogue of Jurassic Bryozoa, p. 193, 1896.

[2] Structure and Affinities of the Genus Monticulipora, p. 62.

tabulated, thin-walled, polygonal cells. *Chætetes* has comparatively lighter colored, probably more calcareous walls. Its cells increase only by fission, while intermural "budding" obtains in *Monotrypa*. It is said, however, that fission occurs rarely in Monticuliporoidea, which leaves a difference in degree only between these two. *Chætetes* is extinct, but is referable only as a coral. It indicates that the *Monotrypa*, *Monticulipora*, etc., are corals; but that the family *Chætetidæ* should contain *Monticulipora* seems doubtful when *Fistulipora* is placed in a family of its own.[1] Certainly *Prasopora* does not belong in both.

Fistulipora, which is the extreme form of Trepostome as compared to *Monotrypa*, is the very one most approaching the Recent coral, *Heliopora*, which, as shown by Mosely, is an Alcyonarian, with a true tabulate skeletal structure. *Heliopora* has the larger cells, but like *Fistulipora* has autocells among mesopores, called siphonopores. The autocells increase by "cœnenchymal gemmation," *i. e.*, a young autocell arises among siphonopores, displacing several. Siphonopores and mesopores are alike. Also, in the mature region of *Heliopora*, the walls thicken and a wart-like projection stands generally at the siphonopore angle and twelve of them surround the autocell. Structurally the warts are similar to "acanthopores," but the wall of *Heliopora* is highly calcareous, and in thin section one sees primarily the crystalline structure radiating from the normal line or center, while the Monticuliporoid wall, being apparently less calcareous, shows the organic lamination, and the acanthopores have concentric structure. The difference is referable to the degree of calcareous deposit in which all corals differ. The warts on *Heliopora* are due to transverse canals between zooids swelling the cortex unevenly. Acanthopores might well be of like origin, and if so they indicate a canal system like that in Alcyonaria.

It has not been clearly enough understood that Mosely[2] demonstrated the *Heliopora* to have no mesenterial septa, but that twelve vertical ribs in each autocell are pseudosepta; and

[1] EASTMAN, op. cit., pp. 102, 103. [2] Challenger Report.

as such they can be compared exactly with the inflections produced by acanthopores in many Monticuliporoids, if the small difference in calcareousness of skeleton be considered. More calcareous ones have sharper processes. A lunarium is wanting in *Heliporidæ*, but this structure is absent in *Fistulipora* in part, and in most Trepostomata. Any structural differences between *Heliopora* and *Fistulipora* are found further in some genus or other closely related to the former, except the monticules or maculæ of the latter.

If one places all Trepostomata and the Tabulata (Alcyonaria) together, they are compared as follows: The largest cells of the former are scarcely equal the smallest autocells of the latter. Growth habit is alike. Cells, monomorphic or dimorphic, are alike; except that distinct pseudosepta in autocells are common in Tabulata, being absent in few cases and these when the walls are very similar in structure to that of Trepostomata, *i. e.*, when crystalline radiate striping is absent,—except also that mural pores cross the walls of many Tabulata, not, however, in dimorphic forms nor in monomorphic ones with small cells,—except again, the lunarium of Fistuliporidæ and the so-called dorsal septum of Alveolitidæ. Notably, the two lunarial angles, forming two pseudosepta, are on the upper side in the former, the single "septum," pseudoseptum, is on the lower side in the latter; the structures therefore not corresponding. If, however, they be ascribed respectively to the double ventral folds and the single dorsal fold of certain Alcyonarian Recent corals,[1] one finds them all represented in Cœnites, a Paleozoic tabulate coral. They are rarely indicated in skeletal structure of either Monticuliporoidea or Tabulata, but argue Alcyoranian affinities.

Cell increase is not unlike. In the Tabulata (Alcyonaria) it is by fission, unequal fission, stolonal gemmation, and intermural gemmation, which are probably degrees of transformation.[2] Intermural gemmation is the rule in Trepostomata. The peculiar

[1] See further, Neues Jahrb. Minn. Geol. and Pal. Beilb. X, pp. 316, 320.

[2] See op. cit., pp. 281, 359.

cell development known as cœnenchymal gemmation occurs in both, and they are not distinguished.

But Trepostomata generally have *monticules* or maculæ, which Tabulata never have; and therein is the one important distinction. But this also argues their relationship, for the Tabulata, comprising three divisions, can be held as the Paleozoic ancestors and representatives of the Alcyonaria as to three of four divisions respectively, the fourth having no known ancestor, unless the Monticuliporoidea be so considered.[1] Among those of the fourth division *Renilla et al.* show a budding and grouping of the dimorphic zooids similar to or like that which must have obtained in the monticulate *Prasopora et al.* The absence of tabulate skeleton in *Renilla* would be explained as in the case of other Alcyonaria, and need not be recounted here. The supposed relation of Monticuliporoidea and Pennatulidæ I formerly considered as based on deduction and slight evidence, and the explanation of monticules is corroborative.

These same monticules and maculæ, on the other hand, bind the Monticuliporoidea together, *i. e.*, Trepostomata to Cryptostomata. In the preceding paragraphs the relation of Trepostomata to Alcyonarian corals is discussed without the Cryptostomata, but these would not change the argument as given if included. They are generally supposed to be Bryozoa, and are important to that side of the question which will be given later. There is in fact no character in the Monticuliporoidea to separate them from the Tabulata, corals. Their separation, if accomplished, would rest upon stronger evidence binding them to undoubted Bryozoa.

EXPLANATION OF PLATE A

FIG. 1. Monotrypa magna Ulr., cell pattern. × 10.
FIG. 2. Monotrypa magna Ulr., vertical section of cells. × 10.
FIG. 3. Diplotrypa limitaris Ulr., cell pattern. × 10.
FIG. 4. Diplotrypa limitaris Ulr., vertical section. × 10.
FIG. 5. Callopora multitabulata Ulr., a small zoarium, natural size.

[1] Op. cit., p. 349.

FIG. 6. Callopora multitabulata Ulr., *a*) cell in axial region, *b*) vertical of same, *c*) vertical showing peripheral cell region, *d*) cell pattern of peripheral region. × 10.

FIG 7. Prasopora simulatrix Ulr., zoarium, natural size.

FIG 8. Prasopora simulatrix Ulr., cell pattern. × 10.

FIG. 9. Prasopora simulatrix Ulr., vertical section. × 10.

FIG. 10. Batostoma fertile Ulr., *a*) cell pattern × 10, and *b*) surface. × 20, showing mesopore' stabulaæ.

FIG. 11. Eridotrypa mutabilis Ulr. surface × 20, showing calycals. After Ulrich.

FIG. 12. Anolotichia impolita Ulr., cell pattern. × 10.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.,
November 5, 1900.

THE EXCURSION TO THE PYRENEES IN CONNECTION WITH THE EIGHTH INTERNATIONAL GEOLOGICAL CONGRESS

THE origin of the ancient crystalline rocks of the earth's crust is a subject which has always possessed a peculiar interest for geologists and which, now that the progress of investigation seems to bring the solution of the various problems connected with these rocks almost within our reach, has a greater attraction than ever.

One of the most important lines of evidence bearing upon this question is that derived from the study of the contact zones about intrusive masses, but the effects produced by many of these intrusions have been differently interpreted by different observers.[1] In France especially, Michel-Lévy, Barrois and Lacroix have described intrusive granite masses, which have not only intensely altered the strata through which they pierce but which have produced a wholesale transformation of the sedimentary rocks in question into granite, the granite now occupying the space formerly occupied by the sediments. If this be the origin of granite, a knowledge of the fact would have an important bearing on the interpretation of many occurrences in the Archean, but the great majority of geologists have been unable to find evidence of it in their respective countries. The French Pyrenees have, however, been cited by Lacroix as a district in which these remarkable transformations could be seen with especial clearness, and in connection with the International Congress of Geologists held last summer in Paris, an excursion to the Pyrenees was accordingly arranged, under the leadership of Professor Lacroix, in order that the members of the congress might have an opportunity of seeing these transformations in the district made classic by Professor Lacroix's work. It is proposed in the present paper, first

[1] ADAMS, F. D.: A review of some recent papers on the Influence of Granite Intrusions upon the Development of Crystalline Schists. JOUR. GEOL., Vol. V, 1897.

to give a short account of this excursion and then to discuss briefly some points in connection with the explanations offered by Lacroix of the phenomena observed.

Leaving Paris on the morning of August 3d on our way south to the rendezvous of the excursion at Ax-les-thermes, the great Tertiary plain of northern France was first traversed. The country as far as the eye can reach is quite flat and excellently cultivated. The grain had just been cut and stacked, and the country in appearance afforded a marked contrast to those portions of the southeast of England underlain by rocks of the same age, in the entire absence of the picturesque hedges and of standing timber. The train then gradually ascended the table land of the Plateau Central, from which far to the east rose the volcanic peaks of the Auvergne, and the country assumed a more rolling character. Descending from this plateau on its southern side over strata of Jurassic age, past Brive and Souillac, the landscape underwent still another change, the country becoming in many places rough and broken, with great exposures of bare rock on either side, through which the train threaded its way in numerous tunnels and rock cuttings, and as the night closed in reached the old city of Montauban. Next morning, passing over the Tertiary basin of southern France, through Toulouse and up the wide low walled valley of the Ariège, Foix was reached, about which place the valley narrowed and the foothills of the Pyrenees rose high and abrupt on either side. Thence passing on by Tarascon the train reached Ax-les-thermes, a picturesquely situated little town, lying well within the Pyrenees, whose hot springs and baths annually attract a large number of visitors, chiefly from other parts of France.

Here the members of the congress who were to take part in the excursion, twenty-eight in number, coming from various parts of Europe and America, were received by Professor Lacroix. Five of the party only claimed English as their native language; Mr. Arnold Hague, Professor Wolff and Dr. Ries representing the United States, while Mr. Kynaston, of the Geological Survey of Scotland, represented the United Kingdom.

The following day, August 5th, the regular work of the excursion began, two visits being made, from Ax-les-thermes as headquarters, on consecutive days, to the contact of a large mass of granite, several miles to the northeast of Ax-les-thermes in the heart of the Pyrenees, with a series of shales and limestones believed to be of pre-Cambrian age. The exact age of the granite is not known but it is younger than the Carboniferous and older than the Lias.

The contacts seen on the first day, were chiefly in the vicinity of the beautiful little L'Etang de l'Estagnet, from which there rise on either side great walls of bare rock, and well graded talus slopes affording abundant exposures. (See Figure 1.)[1] The normal granite of the district is light in color, poor in iron magnesia constituents and contains large porphyritic feldspars. It often shows marked evidences of dynamic action. The shales near the contact are hardened, being converted into a hornstone, said by Lacroix to be in many places "feldspathisé," but the most interesting feature of the excursion was the contact of the granite with the limestone. This limestone, which is gray in color and highly crystalline, contains many little bands of silicates, representing impure laminæ in the original rock, which, especially on the weathered surface, emphasize its stratified character in a most striking manner and often display the most complicated contortions. The limestone in its whole character and appearance exactly reproduces many occurrences seen in the more altered limestones of the Hastings Series in the Archean of Canada.

Between the limestone and the granite, however, there is a zone of rock, often very narrow but in some places, according to Lacroix, as much as 800 meters wide, more basic than the granite and termed by Lacroix, "Diorite" or "Roche Dioritique." This completely surrounds certain isolated occurrences of limestone and is believed by Lacroix to have been produced by the

[1] For the photographs which illustrate this paper, with the exception of that reproduced in Fig. 2, the author is indebted to Professor Heinrich Ries, of Cornell University.

granitic magma, before crystallization, dissolving a portion of the lime-stone, incorporating it, and thus being rendered more basic, crystallizing out as a diorite about the contact. This "Roche Dioritique," while as a general rule tolerably uniform in appearance, often presents rapid variations in size of grain from fine to coarse, and in other places passes into more basic forms such as norite and even into varieties holding olivine.

The excursion of the second day took the party to another portion of the periphery of the same granite mass in the wild district about the L'Etang de Baxouillade (see Fig. 2) and the Cirque de Camp Ras. The route followed led first over the granite, which as the contact was approached was seen to hold a few dark inclusions, which certain of the petrographers present at once set down as basic secretions from the magma. These, as the little L'Etang de Baxouillade was passed become more numerous and often presented the appearance of having been softened and drawn out. Further on at the Cirque de Camp Ras the granite comes against a mass of shale interstratified with limestone. Both of these rocks are highly altered, the shales being converted into dark hornstones and the limestones into paler lime hornstones, consisting chiefly of a basic feldspar and pyroxene. Along the immediate contact of the granite, there appears to be evidence that the dark inclusions before mentioned are masses of hornstone which have been separated from the walls, caught up by the granite magma and more or less softened —or in the case of the lime hornstone dissolved, giving rise to irregular shaped masses of the "Roche Dioritique" before mentioned. One block of gneissic granite about two feet long was observed, at one end of which, embedded in the granite was a mass of the light-colored hornstone enclosing a mass of unaltered limestone, while at the other end of the same block, the granite contained small masses of "Roche Dioritique," which certainly presented the appearance of dissolved fragments of the same limestone. The only other explanation of the origin of these darker-colored masses in the granite is that they are basic secretions from the granite magma itself, about the margin of the mass,

but the appearances in the field rather favor Lacroix's interpretation.

The next day the party, leaving Ax-les-thermes, drove to Foix, visiting on the way the gypsum quarries near Tarascon. The gypsum is of Triassic age and is seen to have resulted from the alteration of anhydrite. It contains intercalated marly beds holding dipyre, tourmaline and other minerals, which are believed to have been developed in them by an intrusion of ophite, which however is not exposed in the immediate vicinity.

On August 8th a visit was paid to a great mass of "Cipolin," intercalated in the gneiss near Arignac, which is locally rich in various minerals of the humite group and containing also spinel, plogopite, rutile, etc. The name "Cipolin" is given by the French geologists to any crystalline limestone intercalated in gneiss, even although it be free from the micaceous minerals which give to the typical "Cipollino" its distinctive character. This mass is from 200 to 300 meters wide and is identical in character with the limestone found in many parts of the Laurentian in North America. The enclosing gneiss is said by Lacroix to contain garnet, and also to differ somewhat in other respects from the granite of the vicinity of Ax-les-thermes. Its origin is unknown.

In the afternoon other large exposures of crystalline rocks near Cabre were visited. These consisted of epidosite, quarried for road metal, containing large lumps of malacolite in places and traversed by little graphite seams. This epidosite is believed to be an altered limestone, and is interstratified with bands of a peculiar dark fine-grained micaceous gneiss, exactly like that which is so uniformly associated with the limestones of the Laurentian in Canada and in the Adirondacks. The age of these crystalline rocks has not as yet been determined.

In the evening the party reached Vicdessos, some seventeen miles west of Ax-les-thermes, a most picturesquely situated little mountain village, from which excursions were made on the two following days. Our route on the first of these days led up to the quaint little village of Sem, where the renowned iron

mines of Rancié were visited. The deposit here consists of a large body of limonite of irregular shape, enclosed in Silurian limestones and shales, and nearly coinciding with them in dip. It is worked by a series of levels the lowest of which is at Sem. This ore body which is very extensive has been mined for ages and formerly supplied ore to as many as fifty Catalan forges, which were in blast in the vicinity. The ore which is handled in a rather primitive manner is now sent to Tarascon, where it is smelted in the blast furnaces situated there. The limonite which makes up the mass of the deposit that has been worked up to the present time, is derived from the alteration of spathic iron ore into what the ore body changes in depth.

Taking a little path up the mountain beyond Sem, a summit marked by the Croix de Ste. Tanoque was reached, where an occurrence of lherzolite is well exposed. This is the original locality of the "Lherzoline" or "Lhercoulite" of Cordier, who mistook the somewhat altered and serpentenized rock for a distinct variety, to which he gave this name. The Jurassic limestones are here penetrated and altered by the intrusion, being bleached and crystallized, while the blocks of the light colored dipyre hornstones found near the contact are considered by Lacroix to be impure or marly bands which were interstratified with the limestones and which by virtue of their peculiar composition were able to fix the exhalations from the lherzolite, which the limestone was unable to do, and in this way to yield a rock rich in dipyre, microline, orthoclase and a variety of other silicates, the original differences in the composition of the beds becoming accentuated through the action of selective metamorphism.

Leaving Vicdessos the following morning, the party traversed the forest of Freychinède, climbing up great exposures of the Jurassic limestone, blue in color and often brecciated, the color being bleached out in spots and streaks precisely as in the Jurassic limestones of the Alps. In these limestones are several occurrences of lherzolite and ophite, which according to Lacroix have the form of laccolites, and which alter the limestones

as described in the case of the occurrences near the Croix de Ste. Tanoque. Passing out of the forest and over the high pastures of the Col de Massat, where a number of shepherds and and cowherds in their picturesque dress were met, the party descended to the renowned L'Etang de Lherz, a beautiful little tarn, by the side of which the original lherzolite is seen. Here a great mass of this rock, dark brown on the weathered surface, penetrates the Jurassic strata, forming by far the most important occurrence of lherzolite in this portion of the Pyrenees. After lunch by the shore of the lake, the mist which had been gathering during the morning settled down as rain, and the party were obliged to hurry on to Massat, the "chef-lieu" of the canton, one of the most secluded little places in the Pyrenees, and one of the few places where the peculiar local costumes of the peasants of the Pyrenees still survive.

From Massat, early on the morning of August 11th, the party drove to Saint-Girons, stopping on the way to examine two or three ophite occurrences and at the Pont de Kerkabanac to see a contact of granite with schist. On the rocky bank of the little stream at this point the granite is seen breaking through the schist and including many little fragments of it. These are often angular, but in some cases appear to have been softened and somewhat drawn out. The "granitization" of these schists was said to be particularly pronounced. The appearance of the contact, however, was like that of any other ordinary granite contact, where the igneous rock has broken through a shattered mass of shale, caught up the fragments and baked them intensely.

At Saint-Girons the train was taken to Bagnères-de-Bigorre, another locality in the Pyrenees renowned for its thermal springs and hot baths, where during the afternoon the party visited the museum of Mr. Charles Frossard, rich in collections illustrating the natural history of the Pyrenees, after which they inspected the extensive marble cutting works and the baths.

About two miles from Bagnières-de-Bigorre is Pouzac, the well-known nepheline syenite locality. This rock, together

with two masses of ophite, is exposed by the side of the railway line, cutting a series of limestones interstratified with marls, which is supposed to be of Triassic age. But little can be seen of the mutual relations of the several rocks or of their contacts. Lacroix states that the nepheline syenite and the ophite appear as little masses penetrating the Triassic limestones. He thinks the nepheline syenite is later in age than the ophite, which seems to surround it, but there appears to be no evidence from their field relations which makes it improbable that they are differentiation products of the same magma. The occurrence of the nepheline syenite, from which all the Pouzac material in collections the world over is derived, is barely sufficient in size to furnish a working face for a single small quarry. (See Fig. 3.) The rock is much decomposed, the sandy disintegration product being used for repairing the roads in the vicinity, but fresh material may be obtained from the numerous bowlders of decomposition. Small bostonite dikes occur in the limestone near the contact. The marly beds are filled with dipyre and the limestones contain little albite crystals, both minerals being attributed to the metamorphosing action of the ophite. The ophite itself is in many places filled with dipyre, which is, however, believed by Lacroix in this case to be the result of weathering.

On leaving Bagnières-de-Bigorre the party drove up the valley of Campan to Payole, a remote hamlet in the mountains, near which a quarry has been opened in a marble of Devonian or Carboniferous age, the stone being sent to Bigorre to be sawn and polished. The rock, which is known as Marbre de Campan, has a reddish or a grayish color and a linear brecciated structure, which produces a handsome effect on the polished surface, and which appears to be caused by certain laminæ in in the rock, rich in carbonate of lime, breaking apart under the pressure to which the rock has been subjected, while the intervening laminæ, rich in argillaceous matter and more plastic, have been forced in between the calcareous fragments and now cement these together.

One of the most interesting granite contacts seen on the excursion was reached from Payole, that, namely, of the Cirque d'Arbisson. Leaving Payole early in the morning on August 13th the party made their way through the Bois d'Arreiou-Tort and up over the moraines mantling the valley bottom and the lower slopes, and after several hours climbing reached the foot of the great Cirque. But little rock is exposed on the way up, but at the Cirque itself, whose walls tower up in the form of a great amphitheater of bare rocks skirted with talus piles, the exposures are magnificent. (See Fig. 5.)

The rocks composing the Cirque are Upper Devonian in age and consist of thinly banded strata, greatly contorted and twisted, and now converted into hornstones of several kinds, varying in character with the original composition of the rock. The unaltered rock was not seen, but it would seem to have been not unlike that worked in the quarries near Payole. The argillaceous bands, however, were probably more numerous and some of the bands were highly siliceous. The contortions and the breaking apart of the harder bands with flowing of the relatively softer layers, in this case the limestones, between the fragments is excellently seen. (See Fig. 6.) The original marly beds have been converted into epidote hornstones, while the more siliceous beds are converted into a flintlike material which is much darker in color. Some of the limestone bands, although greatly contorted, have retained their fine-grained texture and blue color, but owing to the shearing movements to which they have been subjected they have assumed, as is frequently the case in such occurrences, a sort of schistose structure. The limestone, however, is usually traversed by little streaks, coarser in grain and whiter in color, marking the first stage of a recrystallization and passage into marble. The limestones or calcareous bands in places contain large crystals of red garnet, resembling the well-known occurrences on the Stikine River, although the development of the crystals is not so perfect. Beautiful flat rosette-like groups of vesuvianite crystals also occur in places along the bedding planes, usually between the layers of epidote

hornstone and the more siliceous bands. A few granite dikes and a mass of granite, apparently of comparatively small dimensions, occur on one side of the Cirque, while the other side is free from granitic intrusions. In these dikes, and also in the hornstone near the contact, axinite occurs in masses of considerable size. In the dikes this mineral occurs as rather coarsely crystalline streaks, in some cases on the walls and in others within the dike itself. In the hornstones it occurs as an impregnation, apparently partially replacing the other constituents of the rock. The petrographical character of the various rocks can be well seen in the immense talus piles at the foot of the cliffs, which also afford an excellent opportunity for collecting. From a petrographical standpoint this was one of the most interesting localities visited on the excursion.

The excursion, as originally planned, was to have terminated here, the party returning to Bagnières-de-Bigorre and then taking the train to Paris; but the majority of the party willingly accepted the proposal made by Professor Lacroix to extend the excursion by another day and visit Barèges. Accordingly, they left Payole on the morning of August 14th, and drove to Gripp, and thence walked to the Col du Tourmalet, over a great series of highly inclined and more or less altered clay slates, limestones, etc., of Upper Silurian and Devonian age. Magnificent views of the Pic du Midi, the highest point of the French Pyrenees, were obtained at a number of points along the route. The ascent was long, the day very hot, and shade by no means so abundant as could have been wished, but the Col du Tourmalet was at length reached, and the very abrupt descent made into the valley of the Bastan, over magnificent rock exposures. The granite appears near the head of this valley, and at its contact with the stratified series there appears a mass of rock consisting of a mixture of actinolite and axinite. The contact was not seen by the writer, but Professor Wolff, who saw it, states that the margin of the granite seemed to be well defined, although somewhat melted into the actinolite axinite rock above mentioned. As the evening was closing in, however, there was

not sufficient time to make a study of the relations of the intrusion, the party being obliged to press on to Barèges.

The valley of the Bastan, in which Barèges is situated, is an excellent example of a valley half filled with morainic material, which is now deeply trenched and for the most part removed by the present stream. Patches of the moraine still remain adhering to the sides of the valley high above the present stream level. Great spaces swept bare by avalanches, here so destructive, can be seen at intervals, and high up on the steep slopes the terraces built by the French forestry department and by them planted with trees to prevent the snow from moving on certain of the more dangerous of the upper slopes, and in this way to avoid a repetition of the disastrous avalanches of former years.

At Barèges the excursion was brought to a close. The majority of those taking part in it, having on the following morning inspected the mineral springs for which the locality is renowned, left for Paris on the afternoon of August 15th, while a few members extended it by still another day and made a visit to the Cirque of Gavarnie, at the head of the Gave de Pau on the Spanish boundary, which is certainly one of the grandest spectacles in Europe, suggesting somewhat the great cliffs of the Yosemite valley (see Fig. 4).

The excursion was planned with the greatest care, and all the arrangements were personally supervised by Professor Lacroix, to whom the sincere thanks of the excursionists are due. Sleeping, as the party was obliged to do almost every night, in some remote mountain village, which was usually taxed to its utmost capacity to accommodate such an unusual influx of visitors, it was very difficult to make satisfactory arrangements in every case. Whatever comfort was to be had, however, the party enjoyed, and the excellent weather contributed greatly to the success of the excursion.

In entering upon a critical discussion of the phenomena observed, the writer feels that great care must be exercised in forming a judgment from what was of necessity a rapid and

more or less incomplete study of the several occurrences. The members of the excursion were, moreover, at a serious disadvantage in not having any geological map of the districts visited. It was never possible to ascertain, except in a most general way, the areal distribution of any rock, the extent of any intrusion, or the distance to which any metamorphic changes could be traced. In preparing these notes, however, the information obtained in the field has been extended by a careful study of Professor Lacroix's published works, so far as they bear upon the localities in question, and a considerable number of thin sections of the rocks collected from the various occurrences, have also been examined.

In those cases where the granites of the Pyrenees were seen in contact with limestones, as, for instance, in the occurrences about Lac L'Estagnet, Pic du Camp Ras and Cirque d'Arbisson, the limestones near the contact were observed to contain various silicates which had crystallized out in them, as described above. Lacroix considers that in these cases, original differences in the composition of the beds influenced the nature of the minerals developed by metamorphism, but that the material for their growth was largely supplied by emanation from the intrusion. He believes that in the case of bands which were originally pure limestones, the minerals produced are garnet, epidote, zoisite, pyroxenes, amphiboles, quartz, feldspars and axinite. Where the original beds were impure, through the presence of siliceous or argillaceous materials, they are transformed into epidosites, garnet rocks, or feldspathic hornstones. Such limestones with silicates scattered through them, are not, of course, peculiar to the Pyrenees, they are seen in every Archean district in the world where limestones are found. The question always presents itself, as to how far these silicates represent original impurities in the limestone, and how far they are due to exhalations accompanying igneous intrusions. The limestones abutting directly against the igneous mass, even in the Pyrenees occurrences, are often free from these silicates In these contacts, however, the appearances go to show that the limestones

during their recrystallization to marble have had added to them, in certain cases at least, as Lacroix holds, a certain amount of new material, probably from the waters and exhalations accompanying the intrusion; but this infusion of new material seems to be confined to a narrow zone about the contact, and is not by any means a regional phenomenon. In fact, in the occurrences at the Cirque d'Arbisson, some of the limestones of the Cirque itself, while greatly contorted, are practically unaltered in character, still retaining their original blue color and fine texture, and are free from all foreign minerals. The occurrence of axinite about the contacts does not seem to call for any especial notice, seeing that boron exhalations, giving rise to tourmaline, have been recognized as of frequent occurrence in contact zones by all authorities, having been found by Rosenbusch, even in the Barr-Andlau contact zone, which is always cited as affording evidence of the strongest kind, of the absence of metasomatic changes in the rocks about granite intrusions.

As mentioned above, in the district visited on the first two days of the excursion, that is, in the district about Lac l'Estagnet and the Cirque Camp Ras, there is between the altered limestone and the granite a zone, varying greatly in width but usually quite narrow, of what Lacroix terms "Roche Dioritique," and which is considered by him to have been formed by the solution of a portion of the limestone in the granite magma. This rock is said by Lacroix to occur only where the intrusion has limestone as a wall rock. It is a rock generally grayish in color and more basic in appearance than the granite, but of about the same size of grain, varying, however, considerably in grain and character from place to place. Lacroix states that a detailed study of it shows that it is not uniform in composition, but that it varies in minerological composition from a hornblende granite to a basic olivine norite, or even a peridotite. It completely surrounds detached masses of limestone, and has distinctly the appearance in the field of having been produced, as Lacroix believes, by a solution of the limestone along the margin of

the granite. The conditions here are especially favorable for such a process of solution, as the limestone is broken up into a number of disconnected masses, thus exposing a large surface to the action of the granite.

No investigations into the chemical relations of the "Roche Dioritique" have been made, or at least none have been published; its exact chemical composition is unknown. This, however, is a subject on which information is especially required. It is most important to know in how far the composition of the "Roche Dioritique" approaches that of the normal granite of the district, with the addition of varying amounts of lime. It would seem that processes of differentiation must in any case have been at work in the mass after the solution had taken place, for it seems difficult to understand how any addition of lime to a granite magma can produce a peridotite. The only alternative, if this view of the origin of the mass is to be sustained, is to suppose that the exhalations given off by the magma first impregnated the invaded limestone in some places with minerals rich in iron, elsewhere with those rich in magnesia, and having thus produced out of the limestone a series of rocks of very diverse composition, the magma bodily dissolved them and thus obtained that irregularity in composition which caused it to crystallize out as rocks of such diverse composition as the mass cooled down.

The appearance in the field, however, in the opinion of the present writer, supports Lacroix's contention that this narrow band of "Roche Dioritique" was produced by the solution of the limestone in the granite magma about the contact. Detailed chemical studies and an accurate map of the area are, however, required before this contention can be proved, and it seems premature to say, as Lacroix does, " L'évidence de la transformation du granite par dissolution du calcaire est complète."[1] The development of this dioritic contact facies seems, even in the Pyrenees, to be unusual, and its volume as compared with

[1] Le granite des Pyrénées et ses Phénomènes de Contact. Bull des Services de la Carte Geol. de la France; No. 64, p. 60.

that of the granite is insignificant, so that while, even if it be established that dioritic rocks may be produced by the solution of limestone in granite, it would scarcely indicate this as a probable origin for the great intrusions of these rocks met with in various other places.

The other class of granite contacts to be considered are those in which the granite comes against slates, shales, and similar argillaceous strata. In the "Livret Guide" prepared for those taking part in the excursion, Lacroix states that there exist in the Pyrenees, notably in the Haute-Garonne and Hautes-Pyrénées, many granite contacts of the ordinary type, long since described, which present the regular and usual succession of spotted slates, spotted or nodular micaceous schists, and andalusite hornstones; but that the contact zones of the Haute-Ariège, visited on the excursion, were chosen because they present striking examples of a much more intense alteration, in character analogous to certain other French occurrences described by Michel-Lévy, which are characterized by a marked "feldspathisation" of the invaded rocks, indicating the "importance prépondérante" of deep-seated emanations in the case of igneous contacts, and affording evidence of a wholesale incorporation of the invaded rock.

"Au contact immédiat du granite, en effet, s'observe une zone constante dans laquelle les schistes et aussi les quartzites se chargent de feldspaths, soit par imbibition, ces minéraux jouant le même rôle que le quartz dans les schistes micacés, soit par injection en nature du granite lui-même. Il est possible de suivre, pas à pas, tous les stades de feldspathisation et les passages insensibles entre ces schistes feldspathisés (Leptynolites) et le granite lui-même." In certain cases, as in the valley of the Baxouillade (near the Cirque de Ras), he goes on to say, these two types of "feldspathisation" are superimposed in one and the same rock, giving the invaded rock a gneissic facies, which in certain cases is so pronounced that it resembles a veritable gneiss.

This process of "feldspathisation" may thus, according to Lacroix, take place in two ways, (1) by imbibition, and (2) by the injection of little veins of granite all through the invaded rock.

In the first case the shales next to the granite, in what is commonly called the hornstone zone, which contain, as in all contact zones, more or less biotite, have feldspar developed all through them by emanations accompanying the intrusion, being thus converted into micaceous feldspathic schists, called in France Leptynolites. The usual type of Leptynolite is stated to possess exactly the same structure as the non-feldspathic micaceous schists, but under the microscope it is seen to contain grains of feldspar (orthoclase or plagioclase), which, like the quartz grains in the rock, are allotriomorphic, their form being largely determined by the biotite. The proportion of the feldspar present is extremely variable; the mineral may be present merely as a few grains here and there in the rock, or the proportion may be greater—the feldspar in some cases being more abundant than the quartz—as in the case of some of the Leptynolite from near Baxouillade. When this is the case, and the rock becomes coarser in grain with an abundance of mica, it passes into a veritable gneiss.

In the second case the granite is injected at intervals in the form of little veins between the lamellæ of the schist, the veins when followed out to their feather edges fading away insensibly into the schist. This is known as "lit par lit" injection, and also gives rise to a gneiss.

The appearance of the contacts of this class visited on the excursion does not strike the observer as being at all unusual. The explanation which at once suggests itself is that the acid granitic magma which has, by virtue of its acidity, apparently eaten into and dissolved the limestone in certain places and to a limited extent, has not been able to produce any marked effect on the shale. It has forced its way into the shattered strata along the contact, in the usual manner, sending a swarm of little dykes or veins into it in places, and everywhere baking it into a more or less micaceous hornstone-like mass. Fragments of the altered shale, abundant near the contact, less so at some distance, lie scattered about in the granite. These often retain their angular character, but at other times are seen to have been

somewhat softened and pulled out into more or less elongated forms, appearing as dark streaks in the granite. The shale has been recrystallized, as in the case of every hornstone, the phenomenon being, of course, more pronounced in the separated fragments which are completely enveloped in the granite magma. The "lit-par-lit" injection is a not unusual phenomenon of contact in all igneous intrusions, and merely produces a mechanical admixture of granite with shale along the immediate contact of the intrusion without in any way necessarily altering the composition of either rock, or producing anything which is not manifestly a mixture of two distinct rocks. The appearance of feldspar in the altered shale—its "feldspathisation par imbibition"—does not necessarily indicate any addition of material. If there were not alkalies in the shale, the appearance of feldspar in the altered rock would be an evidence of the addition of these elements. But, as the analysis of shales from all parts of the world show, alkalies are almost invariably present, amounting on an average to about 4.75 per cent. This would, in the case of a thoroughly recrystallized rock, afford the material for as much as 25 or 30 per cent. of feldspar, and it would seem that there is seldom more, or in fact as much as this, present in the Leptynolite.

Gneissic rocks of a peculiar type found continually associated with the Laurentian limestones of Canada, and which have precisely the character of the more altered forms of these Leptynolites, when analyzed have been found, in many cases, notwithstanding their content in feldspar, to have a chemical composition identical with that of ordinary roofing slate, being in fact nothing more than shales which are completely recrystallized. On the other hand, thin sections of the most altered leptynolite from Pont de Kerkabanac contain more feldspar than would be expected in an altered shale.

While, then, it is impossible to assert that there has been no addition of material to the altered shale, no evidence seems to have been brought forward that there has been such addition, or that these occurrences differ from the ordinary type of contact

FIG. 1.
Near L'Etang de l'Estagnet.

Ridge of granite in distance. On right, cliff of thinly banded limestone, much altered and filled with garnets.

FIG. 2.
L'Etang de Baxouillade.

In foreground, granite with inclusions of schist and "Roche Dioritique." The mountains in the distance are composed of granite with pre-Cambrian limestone and "Roche Dioritique." The depression in the center of the range is formed by a Permo-Carboniferous limestone, which is altered by the granite.

Fig. 3.
Quarry in Nepheline Syenite—Poussac.

Fig. 4.
Cirque de Gavarnie.

FIG. 5.
Cirque d'Arbisson.

FIG. 6.
Contorted Strata at the Cirque d'Arbisson.

zones. What is required to establish this, is an exhaustive series of chemical analyses of carefully selected material, showing the composition of certain definite beds in their original and altered forms. Such an investigation would be of the greatest interest and highest importance to geological science at the present time.

Although, therefore, it is possible that some of the Archean gneisses which now have no longer the composition of any ordinary sediment, may represent shales which have been transfused with new material by emanations accompanying granitic intrusions, the studies hitherto made of these Pyreneean contacts do not, in the opinion of the writer, afford any conclusive evidence that such emanations have this transforming power. Still further are they from establishing the contention that granitic intrusions are merely great areas of shale or other sedimentary rocks changed in situ into granite, which is the view of their origin held by Michel-Lévy and Lacroix. "Je considère donc toutes ces couches métamorphiques isolées aujourd'hui au millieu du granite comme le résidue non digéré des assises sédimentaires dont le granite á pris la place."[1] "La mise en place du granite s'est effectuée par dissolution graduelle des roches sédimentaires dont il occupe la place."[2] This conclusion would, of course, if established, be of the greatest interest, but the evidence hitherto put forward seems quite insufficient for that purpose.

The metamorphism of the sedimentary strata in the vicinity of the intrusions of the basic rocks (ophite and lherzolite) is also attributed by Lacroix largely to the action of emanations from deep-seated sources. "L'impuissance de la lherzolite à opérer des transformations métamorphiques par l'action de sa propre substance est démontrée par l'absence de zones de passage entre elle et les sédiments métamorphiques et par la nature des minéraux produits à son contact. . . . . La roche modifiée a fourni une partie des éléments nécessaires à la formation des mineraux néogènes, mais beaucoup de ces éléments ont été

[1] LACROIX: Livret, Guide, p. 15.

[2] LACROIX, Le granit des Pyrenées, etc., p. 3.

nécessairement apportés des profondeurs, sous forme d'émanations, ayant une composition chimique différent de celle qu'à priori on pouvait supposer, étant connue la composition de la lherzolite."[1] There is, however, here again the same absence of the chemical evidence which would serve to definitely establish this conclusion.

It is also to be noted that in the Pyrenees, dynamic action has followed the development of the contact zones above described. Lacroix observes that the minerals produced by the contact metamorphism are often much deformed by subsequent movements, but adds: "J'ai pu constater avec précision que les phénomènes de contact jouent un rôle prépondérant dans la production des nombreuses roches métamorphiques que l'on rencontre dans toute l'étendue de la chaîne."[2] As, however, it is a matter of extreme difficulty, if not an impossibility, in all cases to determine to which class of metamorphic agencies certain rocks are due, the question as to how far dynamic action may have at least contributed to some of the changes attributed to contact action is one which cannot be considered as entirely settled.

To sum up therefore it may be said, that while the transfusion of a certain amount of material into the limestones along the immediate contact of the intrusions and also a solution of the limestone to a limited extent in certain cases seems highly probable; the wholesale transformation of limestone into diorite, or of shale into gneiss and granite, which has been described in the case of these contact zones of the Pyrenees, is as yet very far, indeed, from being proved.

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[1] LIVRET, Guide, p. 5.

[2] Les Phénomènes de contact de la Lherzolite et de quelques Ophites des Pyrénées. Bull. des Sciences de la Carte Géol. de la France, No. 42, p. 133.

VALLEYS OF SOLUTION IN NORTHERN ARKANSAS

PROFESSOR G. F. MARBUT has called attention to valleys of solution in Missouri.[1] Before this had come to the present writer's notice, he had become convinced that a type of valley which occurs in large numbers in the Boone chert of Arkansas owes its existence to the differential solution of the rock.

The Boone chert lies at the base of the Mississippian series in Arkansas. Over a large part of the region north of the Boston Mountains, erosion has left this as the surface rock. It approximates 400 feet in thickness and is essentially an immense deposit of limestone containing chert which varies greatly in amount, both horizontally and vertically.[2]

In all places where the Boone chert is the surface rock, the calcareous portion has been partly removed by solution, leaving a residue of chert, in places several inches deep, on the surface. The universal distribution of the small chert particles over the surface reduces the run-off to the minimum and increases the underground water to the maximum. As a consequence, valleys of solution are numerous throughout the region in which this is the surface rock. So different are these valleys from those of corrasion that they attract the attention of even the untrained observer. While seldom of great length, their length is always great in proportion to the width, and the latter is strikingly uniform throughout. To borrow a term from biology, they are always bilaterally symmetrical, and their slopes are steep (Fig. 1). They are remarkably straight, seldom deviating from a straight line more than a few feet except at the points where two valleys unite (Fig. 2). Probably the most striking feature about them is that they head suddenly, the heads often having exactly the appearance of half a sink-hole cut with a vertical

[1] Missouri Geological Survey, Vol. X, pp. 88–92.

[2] For a full description of the Boone chert, see Rep. of the Ark. Geol. Surv., 1890, Vol. IV., pp. 94–107.

plane through the center. Not infrequently the heads are forked, as shown in Fig. 1. The bottoms and slopes are covered with angular residual chert, leaves and branches of trees (Fig. 1). If surface water ever flows through the upper parts of these valleys, it is only after excessive rainfalls. Extended travel over the region has not yet brought to the writer's notice a single case in which the upper part of one of these valleys has been occupied

FIG. 1.

by surface water in sufficient quantity to remove the residual chert.

Unlike the valleys which Professor Marbut describes in Missouri, these valleys are narrow and steep-sloped in their upper parts and pass into rather wide, open valleys which owe their forms to both solution and corrasion. The topographic transition from that part of the valley that is due wholly to solution to the part that is due to both solution and corrasion is of course gradual. The point, as the writer conceives it, where the one passes into the other is determined by the groundwater level. Above the point where the valley cuts into the groundwater, the work is done by solution; below that point a surface stream

exists which adds the work of corrasion to that of solution, the latter occurring mainly on the valley slopes above the stream bed. As this work goes on and the stream bed continues to be reduced more and more below the average level of groundwater,

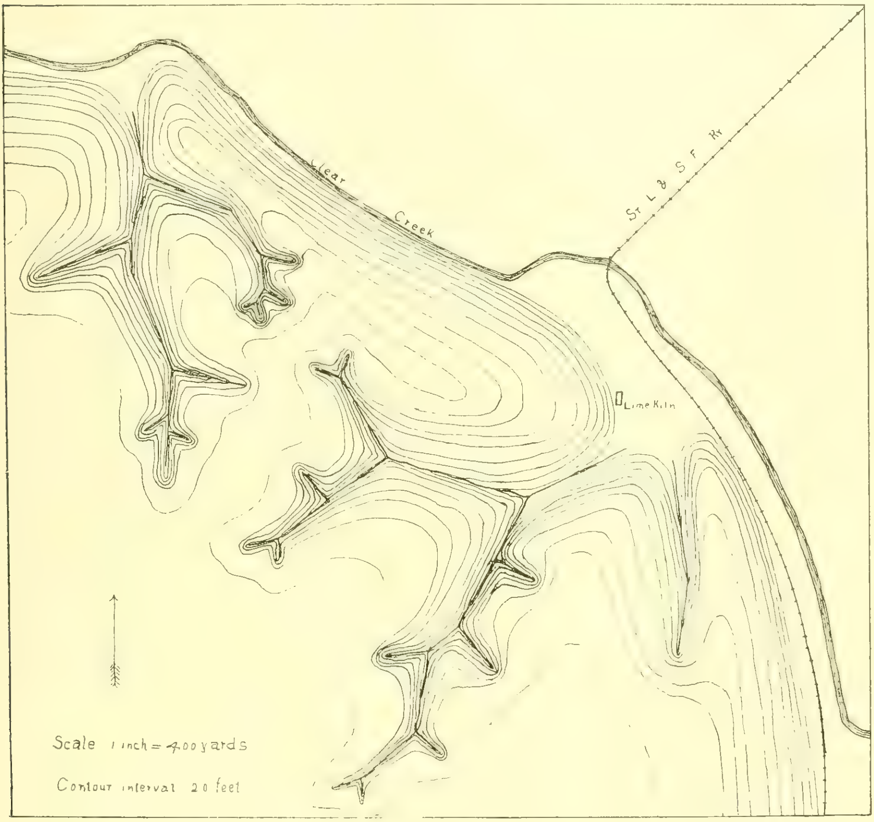

FIG. 2.

the stream grows in size, and in time, by meandering, is able to produce a wide valley.

The point at which the valley cuts into groundwater of course varies with the seasons, but on the whole it is moving up the valley because of the differential solution brought about by the large amount of groundwater moving down the slope from either side and meeting beneath the bed of the valley.

Fig. 2 is a map of two of these valleys with their tributaries, four and a half miles north of Fayetteville. The map was made with a plane-table without correction for magnetic variation. These are typical of valleys that occur in the Boone chert of Arkansas by the thousand. The heavy lines are placed along the bottoms of the valleys only to bring to notice the angles at which they join each other. These angles vary from 60 to 100 degrees or more, the most common one being 80 degrees. It will be noticed that the angles at which the main valleys and their tributaries unite are quite different from those of corrasion.

The writer thinks there can be no doubt but these valleys are determined by the jointing of the horizontal beds of rocks. The double heads which are so common among them are tributary valleys in their incipiency, following joints which intersect along the course of the main valley.

The large valleys which contain the master streams of the Boone chert region were probably inherited, with their streams, from the former superimposed rocks, but the valleys here mentioned owe their origin and development to solution, aided possibly by the removal of part of the residual chert after the most excessive rains.

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Studies for Students

THE STRUCTURE OF METEORITES. I.

Those portions of cosmic matter which from time to time fall to the earth and which are known under the general name of meteorites, have now for about a century been objects of collection and study. Earlier studies of this matter were, on account of its limited quantity and variety, necessarily confined chiefly to the description of individual masses. Comparative study, has, therefore, been carried on to only a small extent and the possible knowledge to be gained by investigation along this line is as yet far from complete. The number of localities from which meteorites are now known may be stated in round numbers as 550 and the total weight of cosmic matter now preserved and in one way or another available for study, as about 161 tons (146,716 kilograms).

Lines of investigation.—The lines along which the study of meteorites has been and is being conducted can be classified as follows, each, of course, being more or less intimately related to or inclusive of the other: (*a*) chemical, (*b*) mineralogical, (*c*) petrological, (*d*) physical, and (*e*) structural. Each of these may be (1) analytical, and (2) synthetical, and may include (3) the study of terrestrial analogies. Of the above courses of investigation the first three have been the lines along which study has been most extensively conducted hitherto. Summarizing briefly their results, it may be stated that the chemical investigation of meteorites has resulted in the identification of twenty-five elements, all similar to those known upon the earth; the mineralogical in the determination of at least twenty mineral species, some of which are similar and others dissimilar to terrestrial compounds, and the petrological in the classification and tabulation of the characters which meteorites display as mineral aggregates.

The physical investigation of meteorites has been confined chiefly to studies of their spectra and comparisons of these with the spectra of comets, nebulæ, and other heavenly bodies. Studies of thermo-luminescence, magnetism and polarity as exhibited by meteorites have also been made. With the results of the structural studies of meteorites it is the purpose of the present paper to deal in some detail.

Structure a feature distinguishing meteorites from terrestrial rocks.—It is from the point of view of structure that meteorites differ most completely from terrestrial rocks. In chemical, mineralogical, petrological and physical characters some meteorites closely resemble terrestrial rocks. The meteorite of Juvinas, for instance, so far as the above characters are concerned, is similar to a basalt, while many of the iron meteorites find a perfect analogue in the terrestrial irons of Greenland. When the structure of meteorites is considered, however, a distinction is apparent. No resemblance to the clastic texture of the Juvinas meteorite is to be found among terrestrial basalts, nor does the terrestrial nickel-iron show satisfactorily the Widmanstätten figures so characteristic of the iron meteorites.

It is along this line of study that the geologist finds problems which his science is especially adapted to solve, for the problems afforded are similar in many respects to those included under the group of structural and dynamical, or, as it is sometimes termed, phenomenal geology. Just as studies of the latter sort avail to give a knowledge of the forces and conditions under which different rock structures and rock movements are produced, so studies of the structure of meteorites may be expected to discover the conditions under which cosmic matter is formed and the forces to whose action it is subject in space. Since, further, this cosmic matter reaching us as meteorites has striking and important analogies with that, not alone of the crust of the earth, but it may be believed also of its entire substance, the fascinating possibility is presented of reading in the mass of meteorites many chapters in the history of the earth which would otherwise be locked up within its interior.

Matter of meteorites of two kinds.— Matter constituting meteorites may be described as of two kinds, metallic and stony. The metallic matter is chiefly an alloy of iron and nickel, the stony matter chiefly the silicates chrysolite, pyroxene, and feldspar. Single meteoric masses may consist of but one of these kinds of matter or may be made up of a union of the two.

Three groups of meteorites according to their components.— According to the relative quantities of each of the two above mentioned kinds of matter it is convenient to divide all meteorites into three great groups. Those made up wholly or largely of metal (*aerosiderites, holosiderites*) form the first group. Those made up of about equal quantities of metal and stone (*aerosiderolites, lithosiderites, syssiderites*) form the second group. Those made up wholly or largely of stone (*aerolites, sporadosiderites*) form the third group. No sharp dividing line can be drawn between these groups. They pass into one another by every gradation, and meteorites of the two kinds even occur in the same fall. Yet meteorites of these groups differ in many essential characters and their separation becomes a matter of great convenience in study. For purposes of the present study the three classes will be sufficiently designated by the terms iron meteorites, iron-stone meteorites, and stone meteorites.

Two groups of meteorites according to their origin. — With respect to their origin meteorites may be either (1) monogenic (of single origin) or (2) polygenic (of various origin). Most of the iron meteorites are plainly monogenic. Many show such homogeneity and uniformity of structure as could belong only to a single crystal. Thus the iron meteorite of La Caille, a mass of 591 kilos in weight, contains inclusions of troilite arranged in parallel rows throughout in such a manner as to indicate a uniform and continuous crystallization of the entire mass. Likewise from a mass of a Toluca meteorite a cube may be cut which shows on etching a perfectly regular octahedral structure throughout. The same parallelism of planes may be traced on an etched section of almost any of the so-called cubic meteorites, such as Coahuila, Hex River, etc. A few iron meteorites

are however plainly polygenic. An etched section of the Mt. Joy meteorite for example shows the mass plainly to be made up of irregular iron fragments. The structure of each fragment as shown by its etching figures is *sui generis*, and indicates an independent origin. The iron of Zacatecas is likewise made up of individual grains the size of a hazelnut to that of a walnut. These are separated by areas of troilite.

Many of the iron-stone and stone meteorites are monogenic but more are made up of two or more different kinds of rock. To draw the dividing line between the monogenic and polygenic meteorites of the last two classes is not an easy task and the opinion of no two observers would probably be the same in regard to it. The meteorite of Stannern for instance was described by one observer as crystalline and by another as clastic. Tschermak, who has given the matter profound study, is disposed to regard practically all stone meteorites as of a tuffaceous or clastic character while Wadsworth after examining many meteorites concluded that none which he had examined could be considered "fragmental in the sense of consolidated cold masses joined together." The present writer can only state that in his opinion some stone meteorites are so uniform in character that crystallization from a single magma is indicated while on the other hand many meteorites have a clearly brecciated and tuffaceous character showing them to be polygenic.

Structures of terrestrial origin to be eliminated.—In all study of the structure of meteorites with a view to learning their preterrestrial history, care should be taken to eliminate all phenomena of terrestrial origin. Thus the crust of meteorites and their surface markings are usually considered, and without doubt properly, to be produced during the passage of the mass through the earth's atmosphere. The possible effects on the interior of a meteoric mass, of heat developed by such passage should also be borne in mind in study. Again the force of impact with which a meteorite strikes the earth is often very great. It should be considered whether such a blow might not give rise to phenomena of internal movement within the mass. Again

processes of corrosion and decomposition go on if the meteorite is exposed on the earth's surface for any length of time, which may have their effect on the structure of the meteorite. These therefore must be judged and eliminated. Again, the fissures found in meteorites are believed by many to be the result of cracking from the sudden development of heat caused by the entry of the mass into the earth's atmosphere and the veins of meteorites are by some thought to be fissures filled by matter fused by such heating. Due weight must be given these possible effects and all that are certainly of terrestrial origin must be left out of consideration.

Uniformity of mass structure of single meteorites.—The iron meteorites usually show remarkable uniformity of structure throughout. Sections from different portions of a single mass or even different masses of the same fall usually give on etching, figures so similar that the meteorite to which they belonged can be recognized at a glance, even if the specimens have been widely separated. In some, however, there are variations in the same mass. Thus the Floyd county iron according to Kunz and Weinschenk while possessing a generally cubic structure shows portions which are granular; the Linnville iron according to Kunz is partly of cubic structure and partly amorphous. The Carlton iron is partly rich in plessite and partly poor in plessite. The Holland Store iron has portions coarse-grained and fine grained. Four of the five masses found near Staunton, Virginia, are quite similar in structure, showing on etching, figures made up of short, swollen bands. The etching figures of the fifth mass are, however, made up of long, straight bands. Moreover the taenite of the first four is brittle, of the fifth elastic. So sharply does the latter mass differ from the others that Brezina regards it as belonging to a different fall, but it is more likely that the differences are those of structure. Such exceptions are however so rare as to emphasize the fact that on the whole iron meteorites are uniform in structure. Speaking in a general way the iron-stone and stone meteorites are likewise uniform in mass characters although such as are

clastic or brecciated have the variations which might be expected from the accidents of aggregation. The monogenic meteorites may show variations from fine grain to coarse grain and vice versa and some portions may contain more stone or metal than others, but the general structure may be said to be uniform.

Similarities of structure in meteorites of different falls.—While the individuals of a single fall are usually similar in structure and composition those of different falls often differ so that they may be easily distinguished. In comparing the meteorites of a large number of falls, however, similarities are readily seen which permit the grouping of several falls together as being of practically identical matter. A number of classifications of this sort have been made of which those of Brezina and Meunier are the latest and most complete. Brezina, who makes structure the leading feature of his classification, has thus reduced all known meteorites to sixty-one groups, while Meunier, with whom mineralogical composition is the chief criterion, makes sixty-two groups.

Degrees of coherence.—The iron meteorites are, as might be expected, usually strongly coherent and tenacious to a high degree of malleability. Yet there are variations in this respect. The iron meteorites showing coarse etching figures can usually be sawed only slowly and with great difficulty, while those of an amorphous or finely crystalline character cut more readily. Some iron meteorites, such as those of Coahuila and Nelson county, can be broken readily by the blow of a hammer. Among the stony meteorites all stages of consolidation may be traced from those of an almost flint-like toughness (Long Island) to those so friable as to crumble on handling (Warrenton). The majority of stony meteorites are fairly coherent so as to take a good polish.

Kinds of structure according to texture.—According to what is often known as rock texture, meteorites display a number of variations which are for the most part entirely comparable with similar variations seen in terrestrial rocks and may be described by the same terms. Accordingly, among the monogenic meteorites

crystalline, cryptocrystalline and vitreous or amorphous structures may be noted. Among the polygenic meteorites, brecciated, agglomerated, psammitic or sandstone-like and tuffaceous structures may be noted. Stratified, foliated, and fibrous structures are entirely lacking. Both among monogenic and polygenic meteorites occurs a kind of structure resulting from the mass

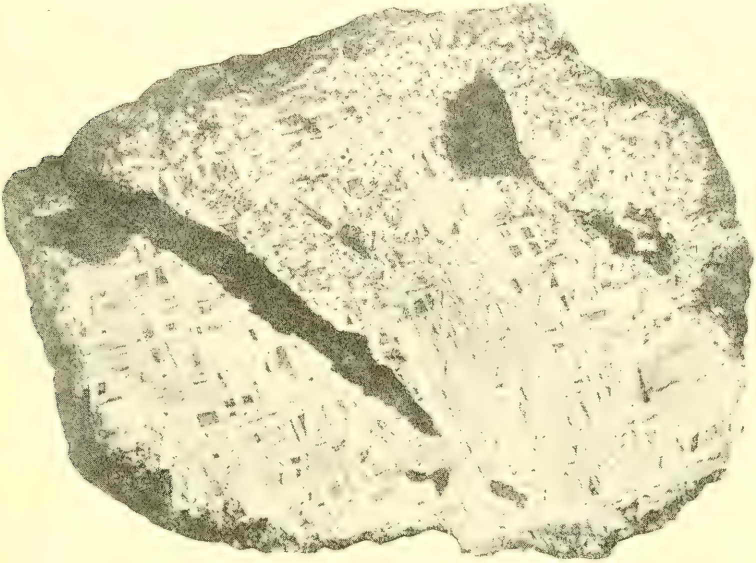

FIG. 1.—Widmanstätten figures. Meteorite from Toluco, Mexico.

being made up largely of little spheres called chondri. The structure of such meteorites is not strictly comparable to that found in any terrestrial rocks. Meunier describes it by the term oölitic, but the analogy is not a very close one. The structure, therefore, requires a distinctive term, chondritic, meaning a rock made up wholly or largely of chondri.

CRYSTALLINE STRUCTURE.

Iron meteorites.—Sections of most iron meteorites when heated or etched by acids or other etching agent display upon their surface well-marked figures formed of series of parallel bands intersecting in two or more directions. These figures

are called, after Alois von Widmanstätten, who first produced them in the year 1808 by heating a section of the Agram meteorite, Widmanstätten figures. The production of these figures is evidence that the meteorites on which they occur (1) have a well-defined crystalline structure and (2) are not homogeneous in composition. Evidence of crystalline structure is not confined to results obtained by etching: many meteorites show in their natural condition a structure of plates intersecting at definite angles. Study of the angles at which the bands meet both in etched and natural specimens shows that the crystallization of most iron meteorites is octahedral, *i. e.*, they are formed of plates or lamellæ arranged parallel to the four pairs of faces of the octahedron.

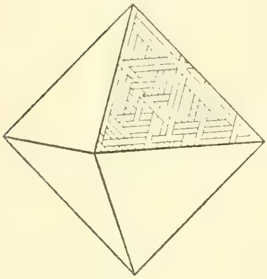
FIG. 2.

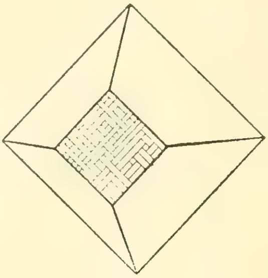
FIG. 3.

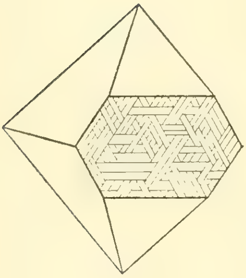
FIG. 4

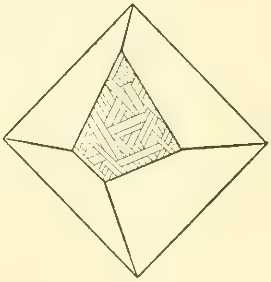
FIG. 5.

Though this arrangement may for practical purposes be considered a simple one, it is really according to Linck the result of a polysynthetic twinning. The angles at which the bands intersect in any given section depend wholly on the direction of the section, as the accompanying figures will show. If the section is parallel to an octahedral face it will show three systems of bands intersecting at angles of 60° (Fig. 2). If the section is parallel to the face of a cube there will be two systems of bands intersecting at angles of 90° (Fig. 3). If the section is parallel

to a dodecahedral face there will be two systems of bands intersecting at angles of 109° 28′ and two others parallel to each other which will bisect this angle (Fig. 4). Sections in any other direction (obviously by far the most common) will produce bands running in four directions and intersecting at unequal angles (Fig. 5). A small number of iron meteorites show a cubic rather than an octahedral crystallization, *i. e.*, they are formed of plates arranged parallel to the faces of a cube. These are known as "cubic irons," or hexahedrites. A still smaller number exhibit no crystalline structure nor Widmanstätten figures. These are known as amorphous irons or ataxites. The relative numbers of these kinds of irons given in Brezina's classification are, of the octahedral irons, 125; of the cubic irons, 26; and of the ataxites, 14. Among the octahedral irons the particular figures exhibited will vary slightly with almost every fall, on account of varying width, length, shape and arrangement of the bands and abundance and forms of included matter. Width of bands is made by Brezina the basis of classification of the octahedral irons. He describes the widths as varying from more than 2.5 ^{mm} to less than 0.1 ^{mm}. When the intimate structure of the bands themselves is considered, they will be found to consist of a broad band of dull luster and iron gray color depressed below the surface when etched or covered with a thick layer of oxide when heated, bounded on either side by thin lamellæ of bright luster and silver white to yellow color, which stand out in relief or are little oxidized. To the broadly banded alloy, Reichenbach, who first investigated this structure, gave the name of Balkeneisen or *kamacite*, from κάμαξ, a pole or shaft. To the narrow banded alloy he gave the name of Bandeisen or *taenite*, from ταινία, a fillet or ribbon. When angular interstices occur between the intersecting bands they are often filled with an alloy intermediate in properties between kamacite and taenite. To this Reichenbach gave the name of Fulleisen or *plessite*. The three alloys together he called "the triad." Chemical analysis of the members of the triad shows them to be alloys of nickel and iron, the first two of which have a fairly

uniform chemical composition, though not sufficiently constant to warrant their being considered distinct mineral species. The percentage of nickel is lowest in kamacite, thus accounting for its greater solubility in acid. The formula Fe_{14} Ni expresses the usual proportion of iron and nickel which it contains. Taenite contains a much larger proportion of nickel and hence is less soluble in acid. Its formula has been given both as Fe_6Ni and Fe_5Ni_2. According to Tschermak the taenite of the Ilimäe meteorite consists of a network of different substances, and it is doubtful whether in any meteorite it is a homogeneous substance. The third member of the triad, plessite, has a very variable composition and the latest investigations make it doubtful whether it differs essentially from kamacite. Inclusions of other minerals occurring in iron meteorites are usually surrounded by a layer of kamacite. Kamacite of this sort, while it does not differ in composition or structure from the ordinary kamacite, has been designated by Brezina as "*wickel-kamazit*" (swathing kamacite) and was called by Reichenbach "Hulleisen." While the octahedral irons always contain two or more of the above alloys, cubic irons contain only one, viz., kamacite. This usually shows a parallel banded structure on etching, but is not divided into well-marked lamellæ. Etched sections of cubic irons also exhibit fine depressed lines called Neumann lines. They are somewhat promiscuously scattered, having neither the abundance nor the regularity of Widmanstätten figures. They are usually interpreted as intercalated lamellæ in twinning relation to the main individual which are more easily dissolved by acid than the other lamellæ. They have been likened to the twinning lamellæ parallel to $-\frac{1}{2}R$ often seen on a piece of calcite. Tschermak regards their formation as simultaneous with the crystallization of the iron, while Sadebeck and Linck consider them of secondary origin, perhaps as a result of jar or shock. Many cubic irons also exhibit orientated sheen (*krystal damast, moiré metallique*). This is formed partly by differential etching

of parallel bands and partly also by the above described Neumann lines. Sheen, Neumann lines, and parallel banded structure of the cubic meteorites will be found on close examination to characterize the kamacite of many octahedral irons (*schraffirten kamazit* of Reichenbach), while the kamacite of other octahedral irons is wholly granular (*fleckig kamazit* of Brezina).

Regarding the part played by the different alloys in the process of crystallization, opinions differ, though the general opinion is that the kamacite crystallized first and the other substances arranged themselves accordingly. Sorby likened the process to the forming of needles of ice on the surface of water, leaving angular spaces which were filled later. J. Lawrence Smith on the other hand, thought that the foreign minerals, such as schreibersite, separated and crystallized first and the purer alloys followed. Huntington is of a similar opinion and draws attention to the close resemblance in appearance between Widmanstätten figures and the arrangement of inclusions of magnetite in mica in support of the view.

Most authorities agree that the crystalline structure exhibited indicates that the masses must have remained for a long time in a fused or viscous state from which they cooled but slowly. The conclusion of Tschermak was that "the greater number of meteoric irons exhibit a structure which indicates that each formed a part of a large mass possessing similar crystalline characters and the formation of such large masses presupposes long intervals of time for tranquil crystallization at a uniform temperature." Sorby reached a similar conclusion and regards the Widmanstätten figures "as the result of such a complete separation of the constituents and perfect crystallization as can occur only when the process takes place slowly and gradually. They appear to me to show that the mass was kept for a long time at a heat just below the point of fusion."

2. *Iron-stone meteorites.*—The metallic portions of most meteorites of this class show Widmanstätten figures on etching. The mineral silicates entering into the composition of the mass also often exhibit well-defined crystal forms, the perfection of which is

sufficient to permit accurate measurements of the crystal planes. A curious feature of these crystals, however, and one which has as yet received no adequate explanation is that they usually exhibit a rounding of the solid angles and edges, giving an appearance of a sphere on which facets have been cut.

3. *Stone meteorites.*—To what extent a primary crystalline structure characterizes stone meteorites, is a point regarding which, as has been said, no two observers are likely to agree. The minerals of many meteorites occur in well crystallized form, but whether they have crystallized *in situ* or are mere splinters from previously existing masses is a disputed point in most cases. The number of stone meteorites showing a holo-crystalline structure similar to that characterizing terrestrial rocks is certainly small. Such as may be of this character are fine-grained and resemble fine-grained basalts in their structure.

Among minerals occurring in well defined crystal forms, whatever their relation to the mass as a whole, enstatite, chrysolite, augite, and plagioclase are the most common and characteristic. The crystals of these minerals usually have well-defined boundaries and exhibit planes corresponding to those of terrestrial minerals of the same kinds. Twinned individuals are common and a lamellar arrangement of inclusions is sometimes seen. There is a complete absence, however, of layers of growth or of zonal structure so common in the minerals of volcanic terrestrial rocks. The crystal individuals often contain large quantities of glass and often present a highly fissile structure. Another remarkable feature is a complete absence of fluid inclusions. Gas pores while occasionally to be seen are exceedingly rare. The latter fact, it may be remarked, furnishes a strong argument against any theory which regards meteorites as having been formed directly from vapors.

CRYPTOCRYSTALLINE AND AMORPHOUS STRUCTURES

1. *Iron meteorites.*—The term amorphous irons or ataxites is usually used to designate iron meteorites which give no Widmanstätten figures on etching. Such irons are few in number and the

present supposed number will doubtless be further reduced by careful study since some accredited meteorites will be found to be artificial irons and others will give Widmanstätten figures on further treatment. The true ataxites resemble ordinary cast iron in structure. There are sometimes variations in a single mass from a compact homogeneous structure to one of a coarse grained character. Several show indistinct broad bands and others a sheen (*Eisenmohr, moiré metallique*) on etching. Inclusions of graphite, phosphides and sulphides of iron (such as schreibersite, troilite, etc.) occur as in the octahedral irons. Unusually high content of nickel characterizes some, while others have an average composition. On the whole the ataxites may be said to form an anomalous and little understood group.

2. *Stone meteorites.*—No stone meteorites are amorphous in structure as a whole; only the ground mass is sometimes found to be of this character. In some cases a ground mass appearing amorphous is found in reality to be made up of consolidated fragments of dust-like minuteness. In other cases, as in the stones of Richmond and Goalpara, the ground mass is really semi-glassy and unindividualized. The ground mass of most of the carbonaceous meteorites is of a black unindividualized character, and appears closely allied to the substance to be described later as forming veins. In the brecciated stones of Orvinio and Chantonnay a black ground mass cements the fragments of chondritic texture together and exhibits a distinct flow structure about them. A brown glass is also found cementing together some of the crystalline and tuffaceous meteorites.

BRECCIATED STRUCTURE.

This is of rather common occurrence. According to Wülfing's classification it characterizes meteorites of sixty-two falls. Breccias occur both of the type of angular fragments compressed together and of angular fragments imbedded in a ground mass which may have been at one time in a fused or pasty condition. Among the iron meteorites the fragments are largest in the Mt. Joy meteorite. The contour of each of these is so distinct that

there can be little doubt that the mass was made up by the aggregation of solid angular fragments. The meteorites of Zacatecas and Kendall counties have a similar structure, though the component fragments are much smaller.

Some of the iron-stone meteorites have likewise a brecciated structure resulting from the imbedding of angular masses of silicates in a metallic base. The meteorite of Copiapo, for example,

FIG. 6.—Brecciated structure. Mt. Joy Meteorite.

has such a structure and its formation is exactly analogous, in the view of Meunier, to the dike breccias produced on the earth by intrusive igneous eruptions tearing off fragments of the rock through which they have ascended and enclosing them in its pasty mass. In this case the intrusive matter was fused nickel-iron. In other iron-stone meteorites, such as Vaca Muerta and Eagle Station, the silicate fragments are likewise angular. Reichenbach is authority for the statement that the iron in these adapts itself to the form of the stone rather than the contrary.

The fragments forming the breccia in stone meteorites are often of considerable size. The largest which I have noted in the stony meteorites (Weston) is about one cubic inch in contents.

Often the fragments differ enough in color from one another, or from the ground mass, so that the brecciated character is plainly visible to the naked eye. In the stone of Weston, for example, the ground mass is gray, the enclosed fragments blue. In the stone of Siena the angular fragments are of a dark color and the enclosing magma is light colored, while of Bandong, Saint-Mesmin and others the reverse is true. In other meteorites the two components differ chiefly in grain and coherence, as in the meteorites of Jelica, Manbhoom, and Soko-Banja. In these the ground mass is of a somewhat coarse, friable character, while the enclosed fragments are of a dark, fine-grained rock. In regard to the ground mass of other brecciated stone meteorites it may be stated that it may itself be made up of rock splinters, *i. e.*, have a tuffaceous character, or it may be crystalline or half glassy. The half glassy ground mass of the Orvinio and Chantonnay meteorites, as already noted, shows a distinct flow structure around the fragments which it encloses.

AGGLOMERATED, SANDSTONE-LIKE AND TUFFACEOUS STRUCTURES.

These may be said to differ from brecciated structure only in the smaller size of the component fragments. The fragments may range from the size of small peas in meteorites of agglomerated structure through that of coarse sand in those which are sandstone-like to that of splinters and fine dust in the tuffaceous meteorites. In the agglomerated meteorites it is often possible to recognize different kinds of rocks. Thus in the Parnallee meteorite Meunier believes he has recognized seven distinct lithologic types. Of the sandstone-like meteorites that of Chassigny is the best example. It is made up of rounded grains of the size of coarse sand. The Shergotty and Ibbenbühren meteorites are likewise granular in appearance. Not all observers, however, agree that the above are clastic in their origin. The tuffaceous structure is a common one in meteorites, Tschermak, as already noted, regarding practically all stony meteorites as of this nature. The resemblance of these to terrestrial volcanic tuffs is very close, though the stratification which usually characterizes the latter has never been

observed. The tuffaceous meteorites are made up of splinters and dust varying in degree of consolidation. They are often finely porous so as to soak up fluids readily. The splinters of which they are made up may be similar in character (Shalka) or strikingly dissimilar (Luotolaks).

O. C. FARRINGTON.

(To be continued)

Editorial

The thirteenth meeting of the Geological Society of America, held in Albany, N. Y., was very satisfactory. The location was sufficiently central to insure a good attendance, the hotel accommodations were excellent and convenient to the place of meeting, and the number of papers was not more than could be read and discussed within the time of the meeting. The local committee, Dr. F. J. H. Merrill and Dr. J. M. Clarke, are to be congratulated on their hospitality and the success of their arrangements.

The postponement of President Dawson's address to the last day of the meeting was regretted by those who were unable to remain through the three days. It would seem advisable to have the presidential address delivered on the second day of the meeting, when there is the greatest number of members present.

The most notable feature of this meeting of the Geological Society, in the city that is looked upon as the cradle of American geology, was the conspicuous absence of a suitable monument to the memory of those pioneers of geological science who have opened a highway to stratigraphy through New York state, and have made of the state a corner stone of the geological structure of the whole country. Such a monument should take the form of a building in which not only the names and records of New York's venerated geologists may be inscribed and their collections preserved, but where their labors may be carried forward and from which inspiration and assistance may spread to geological workers throughout the state. In a state less than New York the absence of such a monument might pass unnoticed.

J. P. I.

The second annual meeting of the Cordilleran section of the Geological Society of America was held on December 28 and 29. The morning session on the 28th took place in the council room of the California Academy of Sciences, in San Francisco. For the succeeding three sessions the members gathered in the rooms of the Geological Department of the University of California.

The following persons were present at the meeting of the section:

W. P. Blake, E. W. Claypole, A. S. Eakle, H. W. Fairbanks, E. W. Hilgard, W. C. Knight, A. C. Lawson, H. W. Turner, F. M. Anderson, W. C. Blasdale, F. C. Calkins, H. W. Furlong, O. H. Hershey, G. D. Louderback, C. F. Newcombe, W. J. Sinclair, J. C. Merriam.

At the first session Professor Wilbur C. Knight was elected chairman, Professor Andrew C. Lawson, secretary, and Dr. A. S. Eakle, councilor for the ensuing year.

In the course of the four sessions the following papers were read and discussed:

The Evidences of Shallow Seas in Paleozoic Time in Southern Arizona. By W. P. Blake, Tucson, Ariz.

In the mountain ranges of southern Arizona there is abundant evidence of shallow seas and shore lines in Paleozoic time. These shores were not, perhaps, a continental margin, but rather the borders of islands, crests of submerged mountain ranges rising at intervals above the Paleozoic ocean and with a trend or direction corresponding eventually to the direction of the mountain ranges of the region.

A cross-section of the territory northeasterly from the Gulf of California shows a succession of mountain ranges, some fifteen in number, in most of which ancient sandstones and conglomerates of Paleozoic age have been identified. Many of the exposures of quartzite are very thick, and these quartzites generally rest upon a coarse-grained porphyritic granite. Deep-sea deposits are not wanting. Thick beds of limestone, especially those of the Carboniferous, give evidence of depressed areas and of oscillations of level. So, also, the existence of thick, uplifted beds of graphitic coal in the Chiricahua Mountains bear testimony to the former existence of land areas, and show a far western extension of the vegetation of the Carboniferous.

Two localities of Devonian beds were described; one in the Santa Ritas and another at the northern end of the Santa Catalina Mountains.

The probable existence of Cambrian beds at several places was pointed out and the ancient tabular gneissic rocks of the Catalinas were referred to the Archean, and regarded as probable equivalents of the Huronian and Laurentian.

The Sierra Madre near Pasadena. By E. W. Claypole, Pasadena, Cal.

The paper opened with an expression of the surprise with which geologists who have worked principally in the East witness the enormous development and the excessive diastrophism exhibited by Tertiary and even by very late Tertiary strata in the West, and these characters are as well seen in California as in any other western state. The whole Tertiary period has apparently been signalized by thick accumulation, with alternate elevation and depression. Not less has its passage been characterized by volcanic outbursts of intense energy and by quiet outflows of lava almost unequaled in massiveness and extent.

Two great mountain ranges diverging in the north and meeting again in Kern county, inclose between them the San Joaquin Valley. This southern meeting forms one of the great natural features of the state — the Tehachapi Divide.

Speaking now only for the southern part of the state, there seems ample ground for the belief that these ranges have existed from at least Cretaceous if not from earlier Mesozoic time. It is not otherwise easy to find a source for the enormous Pliocene, Miocene and Eocene accumulations of the Pacific margin so far from the Sierra Nevada.

Thick gneissic strata of two types, and standing nearly vertical, compose the range of the Sierra Madre near Pasadena. That to the south contains a large proportion of hornblende, weathers rapidly and deeply, and is consequently eroded with comparative facility. That to the north is largely feldspathic, contains little hornblende, and of it consist the white crags that stand out so boldly on the upper slopes. The former of these masses cannot be less than 2000–3000 feet thick, but it does not rise in the mountain to a greater height than 3500 feet.

Of the wreckage from these two gneissic masses the material filling the valley of Pasadena is composed. From great bowlders near the

foot of the Sierra it gradually diminishes till it becomes, in many places, a fine gravel and at last a fine silt. This last composes the adobe land around Los Angeles and also the many sheets of the same material which lie in the gravel, and are the holding-ground of the water supply. This has been so largely exploited during the two late dry seasons that the work has resulted in restoring confidence in the water resources of the valley, of which some had become rather doubtful.

The highly aluminous nature of many of these beds indicates a very extensive decay or kaolinization of the gneisses of the Sierra and together with the diluvial arrangement of the Pleistocene wash in the valley rather indicates a long continuance of the present climatic conditions than a past of greater and steadier rainfall.

The multiplication of wells has not yet shown any effect in lowering the water level unless perhaps in a few cases and this result is the more surprising and gratifying because it comes after two dry seasons in which only eleven inches of rain have fallen. Already this year, a greater total has been received than the above though the wet period has scarcely begun.

When to this is added the storage of the rainwater in tanks and ponds and the reforesting of the Sierras, wherever possible, it will be seen that the maintenance of the water supply in the future is encouraging.

Bates' Hole. By WILBUR C. KNIGHT, Laramie, Wyo.

Bates' Hole, a great natural depression, is located along the east and west boundary line between Carbon and Natrona counties, Wyoming; extending southward from six to ten miles into Carbon county and from twenty to twenty-five miles into Natrona county. The botbom of this depression is 800 feet below the rim near the head and over 1700 feet below it near the Platt River. The drainage is practically confined to Camp Creek which rises at the southern end of the Hole; but which affords water for only a portion of the year, and Bates Creek which rises in the Laramie Mountains and furnishes quite a stream. The country about this area is comparatively level; but to the eastward only a few miles rise the Laramie Mountains, and to the westward the Indian Grove and other ranges, which are made up of Mesozoic, Paleozoic, and Archean rocks. In length Bates' Hole varies from twenty-five to thirty-five miles and in width from six to twelve miles;

the lower end being much the wider. The dominant formation entering into the structure of this region is Tertiary; but this rests nearly horizontally upon a very uneven floor of older rocks, which in the central portion have been exposed and suffered extensive erosion. From the rim the slopes are very steep throughout, seldom being less than 15° to 20° and usually much higher and in many instances from 28° to 34°. Occasionally there are vertical walls of the Tertiary rocks from 100 to 200 feet, carved in the most unusual manner and often cut with deep, narrow, dry gorges. Capping the highest Tertiary escarpments there is a heavy conglomerate of unknown age; beneath this are the Titanotherium beds which have a thickness of about 600 feet, and in local depressions in the Cretaceous series underlying this region there is a third series of Tertiary beds, composed of variegated clays and sands that is in all probability Eocene. Along the Platte River all of the Tertiary rocks have been removed and along the Laramie Mountains there are exposed in natural order, Cretaceous, Jurassic, Triassic, Carboniferous, Cambrian, and Archean as one ascends the range. Along the Tertiary escarpments are numerous stunted pines (*Pinus flexlis*) whose roots are exposed from one to eight feet which signifies very rapid erosion. This erosion has been very general and data that will aid us in determining the age of Bates' Hole are well in hand. Illustrated with lantern slides.

A Geological Section through the John Day Basin. By JOHN C. MERRIAM, Berkeley, Cal.

The John Day River and its tributaries have exposed in the erosion of their canyons about ten thousand feet of strata, giving a full series of formations from Lower Cretaceous to Quaternary.

The oldest rocks in this region, which are known to the writer, are a series of altered sedimentaries in the northeastern part of the basin. They are pretty certainly of pre-Cretaceous age and are underlain by quartz diorite[1] which is presumably intruded into them.

On Bridge Creek, near Mitchell, a great thickness of Cretaceous is exposed. The lower 2000 to 3000 feet of this section are typical Knoxville. The upper 1000 to 2000 feet are Chico.

Resting upon the Chico, near Mitchell, also showing typical exposures at Clarno's Ferry, is a presumably Eocene formation to which the name Clarno is given. This formation is made up entirely of tuffs,

[1] Determined by Frank C. Calkins.

ashes, and lavas. In places it contains many plant remains and is apparently in part a fresh water formation.

The John Day formation rests directly upon the Clarno at Clarno's Ferry. The basin in which it was deposited is quite different from that of the Clarno. It probably rests unconformably upon that formation. The Lower John Day beds are considerably contorted in some localities. Ordinarily they are colored a deep red. Fossil remains are exceedingly rare in this division.

The blue-green beds of the Middle John Day are very fossiliferous. They correspond to the Diceratherium beds of Wortman. The Upper or Buff beds of the John Day lap over the middle division and rest in places upon the older formations. The upper division corresponds to the Merycochœrus Beds of Wortman. As *Merycochœrus* does not occur in the John Day, the upper division will be called the Paracotylops Beds. This name is based on the new generic name proposed by W. D. Matthew for the Upper John Day oreodons, originally supposed to be *Merycochœrus*.

The Columbia lava, an extension of the lavas on the Columbia River to the north, rests unconformably upon the crumpled John Day formation. The name Columbia lava should be restricted to this horizon of the lavas in this region, as other beds included in this group belong in some cases to different geological periods.

The Cottonwood (Loup Fork) formation, near 1000 feet in thickness, rests upon the Columbia lava. The Van Horn Ranch plants, which have generally been considered as John Day, are from this horizon. Remains of a true John Day flora, which had not previously been known, were discovered by the University of California expedition in 1900. The discovery of the true stratigraphic position of the Van Horn Ranch flora explains the apparent inverted position of the Neocene formations in central Washington.

Resting on the worn edges of the Cottonwood Beds is the Rattlesnake formation, comprising several hundred feet of gravel, tuff, and lava.

In canyons cut through the Rattlesnake and Cottonwood are several terraces. Remains of elephants and later horses found in the lower terrace deposits show that they were formed in Quaternary time.

The paper was illustrated with lantern slides showing the principal formations and their relations to each other.

The Geology of the Great Basin in Eastern California and Southwestern Nevada. By H. W. TURNER, San Francisco, Cal.

The ridges of the western edge of the Great Basin in Nevada and eastern California are usually very complex in structure and composition. They comprise sediments of Paleozoic and Jura-Trias age much disturbed at some points by intrusions of granolites. In Tertiary time there were extensive lakes, and contemporaneous with these lakes and also later are lavas and tuffs in large amounts, chiefly rhyolites, andesites, and basalts.

The formation of the ranges, or at least their latest uplifts, date from the late Tertiary and post-Tertiary time.

They were elevated along normal faults, the valleys being in part subsided areas, often of the nature of rock basins, whose rims are composed of rocks older than the desert detritus.

There are some gneisses pretty certainly of pre-Cambrian age. These gneisses underlie Lower Cambrian sediments rich in fossil remains at some points. There is an extensive chert series containig abundant graptolites supposed to be of Lower Silurian age. There are Lower Trias beds in the Inyo Range and Jurassic limestone in the Pilot Mountains.

The Tertiary lake beds contain abundant plant, molluscan, and fish remains.

The paper was illustrated with lantern slides.

Notes on the Geology of the Three Sisters, Oregon. By H. W. FAIRBANKS, Berkeley, Cal.

The Three Sisters form a group of volcanic peaks upon the summit of the Cascade Range in central Oregon. They rise to a height of about ten thousand feet, and are quite similar in many respects to the other great volcanic peaks which mark the crest of the Cascade Range through Oregon and Washington.

This group of peaks is marked by the presence of a glacier nearly three miles long and half a mile wide.

To the north of the peaks recent volcanic activity is indicated by extensive flows of basic lavas. Volcanic eruptions have occurred since the glacial period, as shown by the relation of the lavas to the grooved and polished surfaces. A volcanic cone upon the North Sister lies in the path of the present glacier.

Illustrated by lantern slides.

A Sketch of the Pedological Geology of California. By E. W. HILGARD, Berkeley, Cal.

Owing to the great climatic diversity, the rainfall varying from two inches at the south to as much as eighty inches in the north, even a sketch of the soil conditions of California must take the climates into consideration. The cardinal difference between rock decomposition in arid as compared with humid climates lies in the retardation of kaolinization, as exemplified in the monoliths of Egypt and the granites of the Sierra Madre, as compared, *e. g.*, with the Alleghanies. Hence in northern California and on the higher Sierra Nevada we find loams and clay soils, while at the lower levels and in southern California the soils are "dusty" or sandy, except where derived from preëxisting clay formations, which give rise to "adobe," and in the upper valleys of the rivers of the Sierra, which carry the materials from the higher levels.

Throughout the middle and southern parts of the state, where no rains of consequence fall between May and November, not only is the soil mass usually of extraordinary depth, but is scarcely changed for several, sometimes for four to ten, feet. There is practically no subsoil in the usual sense, in the absence of clay; water, roots, and air penetrate together to depths impossible in the regions of summer rains, and hence the extraordinary endurance of drought, even by plants foreign to the arid region. Moreover, these soils almost universally contain high percentages of lime and potash, due to the absence of the leaching process, which, on the other hand, results in the formation of "alkali soils," too complex a subject to be dealt with here.

"*Sand*" in the arid soils is not merely quartz grains, but consists of all the original minerals, superficially decomposed. Hence sandy lands are here fully as rich as clay lands are elsewhere.

In the Great Valley it is easy to recognize by their microscopic characters the alluvial areas of the several rivers coming in from the Sierra. Even here the greater rainfall of the Sacramento is evidenced by loam and clay lands, as compared with the San Joaquin valley, where sandy and silty lands prevail altogether. As the rainfall decreases toward the Coast Ranges, the "lightest" are found under the arid lee on the west border of the valley. In its axis, in the "tule lands," as well as on the borders of the bays near its outlet, heavy clay soils are being formed in the slack water, while the streams coming from the Coast Ranges are bordered by light silty lands, the "truck lands" from

which San Francisco markets are supplied. Along the foothills of the Sierra there lies a belt of varying width of heavy red clay lands, probably derived from Ione formation, and frequently closely packed with gravel. These materials are intrinsically poor in plant food and being difficultly penetrable by roots, have caused much disappointment to settlers, and were the first to be treated by the energetic method of blasting with dynamite for fruit culture. They improve materially toward the south and in Fresno county form the basis for successful citrus culture. Higher up in the foothills come the characteristic red soils, the gold-bearing earths, mostly derived from the older slates and sedentary thereon. They are interpersed with patches of gray "granite" lands, which are very much less productive, being derived from the granodiorites, deficient in potash and phosphoric acid.

The soils of the Coast Ranges vary greatly, with their varying rock formations, among which are much clay and clay shale, forming correspondingly heavy soils. But the valleys also are filled with deep silty or sandy deposits. Southward the Coast Ranges are continued in the Sierra Madre, which forms the northern wall of the valley of southern California.

This valley, now subdivided into the drainage basins of the Santa Ana and San Gabriel, was undoubtedly originally a unit. This is proved by a terrace of "red lands," which extends all around from Redlands and Riverside to Los Angeles. Its subdivision was effected in late times by the great débris cone of the San Antonio Creek, which abutting against the Puente hills cut the drainage in two. The red soils are the special ones for citrus culture; but the sandy and silty alluvium of the two rivers also serves the same purpose.

The Neocene Basins of the Klamath Mountains. By F. M. ANDERSON, Berkeley, Cal. Presented by Andrew C. Lawson.

This paper is an attempt to show some of the more salient structural features of the Klamath Mountains, including not only their basins, but also their principal ranges. The three chief ranges of the group, extending in a northeasterly direction from the coast, and the drainage basins intervening and otherwise associated, form the main subject of discussion. Of the two systems of ranges crossing each other nearly at right angles, the northeast and southwest ranges are the older, and have exerted a controlling influence over the drainage

since their beginning. The principal rivers of the region — the Rogue River, the Klamath, and the Trinity — cut transversely across the more nearly north and south ranges, showing them to be younger in age than the lines of drainage followed by these streams, and accordingly younger in age than the east and west ranges.

The historical development of these drainage basins is shown by the deposits contained in them, and for some of them it antedates the later Cretaceous epochs at least. The earliest drainage of the basin of the Klamath lakes is shown to have been through the valley of Rogue River, and to have been diverted from that course to its present, by some of the later lava flows from the Cascades. Evidence is cited to show that during the Chico epoch this basin was not connected with that of the Pitt River or the Sacramento, and it is maintained that its individuality has been kept almost unchanged to the present. As one of the larger streams of the region therefore, the Klamath is younger in age than either the Trinity or Rogue River.

On the Age of Certain Granites in the Klamath Mountains. By Oscar H. Hershey, Berkeley, Cal. Presented by A. C. Lawson.

Small batholites and dikes of granite, quartz-mica-diorite and intermediate types are shown to occur at various places in the Klamath region, but in areas quite subordinate in extent to those of the metamorphic rocks into which they have been intruded. The same contains extensive areas of serpentine and instances are given of the granitic rocks having been intruded into the serpentine to prove that the granites are newer, in accordance with the determined relations of these rock types in the Sierra Nevada region, and the reverse of the supposed relation between the granite and the serpentine of the Coast Ranges.

The black slates of the Klamath region are divided into two distinct series, referred to as the Lower Slates and the Upper Slates. The former are considered Devono-Carboniferous in age, being in part equivalent to the Calaveras formation. The latter are correlated, on the evidence of their lithology and of their structural relations to the Lower Slates and to a certain extrusive greenstone formation similar to the diabase and porphyrite formation of the Sierra Nevada region, with the Mariposa formation of late Jurassic age. The intrusion of granite occurred later than the deposition of these Upper Slates. Also it is shown that

the granites are much older than the Chico formation resting on them as they had suffered much erosion prior to the Chico epoch.

It is finally concluded that the weight of evidence places the granitic intrusion just about at the close of the Jurassic period. The effect of the argument is to show that there is a sound basis for the inference heretofore entertained that the Klamath Mountains belong rather to the Sierra Nevada system than to the Coast Ranges and may be considered a sort of outlier to the former.

The Drainage Features of California. By ANDREW C. LAWSON, Berkeley, Cal.

A comparative study of the geomorphy of the Sierra Nevada and the Coast Ranges. There is a remarkable contrast in the character of the river valleys in the two mountain systems, those of the Sierra Nevada being consequent and the geomorphy immature, while those of the Coast Ranges are subsequent and the geomorphy mature. In the Coast Ranges the geomorphic profiles of the river valleys, leaving out of consideration the head-water streams, are not so steep as in the Sierra Nevada, and the valleys are much wider as a general rule. The divides are rounded or ridge like, with but small remnants of the earlier geomorphic cycle identifiable, in the Coast Ranges, while in a large part of the Sierra Nevada the divides have a marked table or plateau form. The drainage of the Coast Ranges is clearly controlled by the structure of the country while the streams of the Sierra Nevada cut *across* the strike of the rocks, and have made but little headway in the working out of canyons *along* the strike of the softer formations.

The Klamath River is regarded by the author as partly having the consequent character of the Sierra Nevada drainage and partly the character of the Coast Range drainage. The Trinity River and its prolongation in the lower Klamath belongs to the Coast Range system being parallel to the strike of the country and in part mature in its development, while the upper Klamath is consequent and young. This affords us a basis for the separation of the Klamath Mountains from the Coast Ranges, and supports the orogenic correlation of the Klamath Mountains with the Sierra Nevada. The comparison thus made points clearly to the conclusion that the Sierra Nevada and probably also the Klamath Mountains are of later date than the emergence of the Coast Ranges which inaugurated the present cycle of geomorphic evolution. But the subsequent valleys of the Coast Ranges are in

several instances known to have been evolved after the deformation of the Pliocene, and we are thus forced to place a very late geological date upon the tilting of the Sierra Nevada orographic block.

A Feldspar-Corundum Rock from Plumas County, California. By ANDREW C. CLAWSON, Berkeley, Cal.

Mr. Turner, of the United States geological survey, has called attention to the prevalence of feldspathic "albitic" dykes cutting serpentine in various parts of the Sierra Nevada. The rock of which the present paper treats apparently belongs to this series of dykes. It occurs as a white coarse-grained dyke cutting the serpentine of the eastern flank of Spanish Peak, Plumas county. The rock is composed of 84 per cent. of oligoclase and 16 per cent. of corundum in crystals up to over two inches in length, and rather irregularly distributed through the feldspathic groundmass.

The following is an analysis of the feldspar:

SiO_2, 61.36; Al_2O_3, 22.97; Na_2O, 8.08; CaO, 5.38; H_2O, 1.72. Total, 99.51; Sp. g, 2.63.

The occurrence is of special interest as one of the rare cases of a rock supersaturated with alumina, and its occurrence as a dyke in a rock devoid of alumina, soda, and lime is of especial interest as supporting a case of extreme differentiation of rock magma.

The foregoing synopses were prepared by the authors of the papers.

JOHN C. MERRIAM.

Reviews

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.

WINCHELL[1] discusses the general structural geology of northeastern Minnesota. The ancient rocks of this area he places in two main systems, the Archean and the Taconic. The former is further subdivided into the Upper and Lower Keewatin, separated from each other by an unconformity. The Pewabic quartzite also is placed with the Keewatin, but is not assigned to either of the main divisions. Overlying the Archean with strong unconformity is the Taconic, represented by Animikie and Keweenawan rocks, these divisions being supposed to represent respectively the Lower and Middle Cambrian of other parts of the country. The Coutchiching and Laurentian rocks before mapped as separate formations are now included within the Keewatin.

The Lower Keewatin comprises greenstone, with associated surface volcanics which are both subaërial and subaqueous, argyllitic slates, siliceous schists, quartzites, arkoses, "greenwackes," iron ores, and marble.

[1] The Geology of Minnesota, by N. H. WINCHELL, U. S. GRANT, JAMES E. TODD, WARREN UPHAM, and H. V. WINCHELL: Final Rept. of the Geol. and Nat. Hist. Surv. of Minnesota, Vol. IV, 1899, pp. 630. With thirty-one geological plates.

Structural geology of Minnesota, by N. H. WINCHELL: Final Rept. Geol. and Nat. Hist. Surv. of Minnesota, Vol. V, 1900, pp. 1–80, 972–1000.

The first of these volumes contains an account of detailed field work in northeastern Minnesota, with incidental discussion of general problems. The area is treated by counties and smaller arbitrary geographical divisions, in the description of which several men have taken part. This manner of treatment leads to repetition in the discussion of the general geological features, and in many cases it is extremely difficult to correlate the facts recorded in the different sections.

Volume V contains an account of the general structural geology of the state by Professor Winchell based on the detailed work described in Vol. IV. This general discussion of Vol. V is reviewed, with such reference to the facts recorded in Vol. IV as is necessary to make the summary intelligible.

Dr. Grant's views, as indicated in the detailed descriptions of special areas, in some cases differ somewhat widely from those of Professor Winchell.

The greenstone, designated the Kawishiwin, is the oldest known rock in the state, and is supposed to represent a portion of the original crust of the earth. With its associated volcanic rocks it occurs in two main belts. The southern belt begins in the vicinity of Gunflint Lake and extends westward by way of Gobbemichigamma Lake, the Kawishiwi River, and White Iron Lake, to Tower, and indefinitely westward. The northern belt of greenstone enters the state from Hunters' Island, appearing conspicuously at the south side of Basswood Lake. At Pipestone Rapids and Fall Lake it widens southward and apparently unites at the surface with the southern belt, the overlying Upper Keewatin being absent for a distance of a few miles. But further west it is again divided by the Stuntz conglomerate, the northern arm running to the north of Vermilion Lake, west of which its extension is unknown, and the southern one running south of the lake.

The fragmental stratified rocks of the Lower Keewatin are most important toward the western part of the area of exposure of crystalline rocks. They occupy a wide area, south, west, and north of Tower. The iron ores of Tower and Ely on the Vermilion iron range occur in the upper part of the Lower Keewatin. It is probable that the immediately enclosing rock is a sedimentary one, although composed of the elements of a basic eruptive. The sediments extend south to the Giants Range of granite, where they are metamorphosed to mica-schists by the granite. Toward the west they extend as far as the Mississippi River and its northern tributaries and across the Bowstring, although the drift prevents the delimitation of the belt. To the northwest they extend toward Rainy Lake, in this direction being converted into mica-schists and gneisses by the intrusion of granite; in unmodified form they are found at one point only on Rainy Lake. These fragmental rocks of the Lower Keewatin doubtless also underlie most of the central and southwestern part of the state as far as the Minnesota River. Here they dip beneath the later formations in the southwestern portion of the state, and probably occupy a wide patch in South Dakota. South of the Giants Range they occur also, but as they are covered by the gabbro and Animikie toward the east and the drift deposits of the St. Louis valley toward the west their geographic boundaries are mostly unknown. They appear in the central and western portions of Carlton county, where their line of separation from the Upper Keewatin is quite obscure, and in the central and western portions of Morrison county. The Lower Keewatin

marble is seen at Lake Ogishke-Muncie and at Pike Rapids on the Mississippi.

The Lower Keewatin was terminated by a period of extensive folding and intrusions of granite and basic rocks.

The Pewabic quartzite belongs with the Keewatin, but whether to the Lower or Upper Keewatin is not known. This formation includes altered quartzites and iron-ores between the granite and gabbro in the immediate vicinity of Birch Lake and small patches of similar rocks in Sec. 30–62–10; on the south shore of Disappointment Lake; on the north shore of Fraser Lake; on the south shore of Gabbemichigamma; at Akley Lake, forming the so-called Akley Lake series extending from the west side of Sec. 34–65–5 to the eastern part of Sec. 27–65–4.

The Upper Keewatin occurs in troughs in the Lower Keewatin, and particularly in one main trough the axis of which is traceable from Vermilion Lake to Saganaga Lake. The northern arm of this syncline, consisting of granites, gneisses, associated mica-schists, and in some places earlier greenstones, extends from the northern part of Vermilion Lake through Basswood Lake to the northern side of Hunter's Island. The southern arm, consisting of Lower Keewatin green-schists and other schists, penetrated by the granite of the Giants Range, extends from Pokegama Falls on the southwest toward the northeast, until cut out by the encroachment of the gabbro from the south. The Upper Keewatin consists very largely of conglomerates, but also includes graywackes, argyllites, quartzites, and jaspilites, in general coarser than those of the Lower Keewatin. Volcanic rocks are less important than in the Lower Keewatin, although still present. There is no general order of succession in the Upper Keewatin excepting that it can be said that it is in general conglomeratic at the bottom.

After Upper Keewatin time both the Lower and Upper Keewatin were subjected to another folding, the axis of which had a general parallelism with the earlier folding, with the result that the Upper Keewatin lies in narrow synclines in the Lower Keewatin and in places is nearly or quite vertical.

Associated with the Keewatin rocks are granites of at least two periods of intrusion, one later than the Lower Keewatin and one later than the Upper Keewatin. The later granite is believed to be represented by the higher parts of the Giants Range and the Snowbank Lake granite. The earlier granite is represented by the granites at Kekequabic Lake, Saganaga Lake, Basswood Lake, Burntside Lake,

Vermilion Lake, Lac la Croix, and Kabetogoma Lake. The origin of the granite is discussed and the same conclusions reached as in a previous article.[1]

The Taconic.— This is unconformably above the Keewatin rocks. It comprises the Animikie and Keweenawan divisions.

The Animikie rocks enter the state at Pigeon Point, run westward along the international boundary to the eastern part of Secs. 22 and 27 T. 65 N., R. 4 W. They reappear again southwestward from Birch Lake on the northwest side of the gabbro mass, and thence continue along the south side of the Giants Range, constituting the Mesabi iron series, to Pokegama Falls. The higher parts of the Animikie are best developed toward the east, while the lower parts are best developed toward the west.

The Animikie rocks comprise the Pokegama quartzite, Mesabi iron-bearing formation, some limestone and slate, all strictly conformable with one another. The thickness is several hundred feet, sometimes reaching nearly 1000 feet. The dip of the series is uniformly to the south, 8° to 12°.

The iron-bearing formation and the Pokegama quartzite constitute the base of the formation. The quartzite in places is beneath the iron formation ; in other places it is in the same horizon ; and in still others is above the iron formation. Commonly the base of the Animikie is marked by a conglomerate, containing débris from the underlying Keewatin rocks. This is a narrow horizon which soon graduates upward into a quartzite, known as the Pokegama quartzite, from its typical development near Pokegama Falls on the Mississippi River. The thickness of the quartzite is not known to exceed fifty feet, and is sometimes less than twenty-five feet.

Above the quartzite, or in alternating beds with it, or below it, appears the iron-bearing or taconyte member of the Animikie, which contains the iron ore deposits of the Mesabi iron range. The ore is usually hematite in the western part of the range and magnetite in the eastern part. It was previously supposed to have been derived from the alteration of a greenish glauconitic sand-rock ; but later work has seemed to show that the green-sand is a volcanic sand, and that the so-called taconitic rock itself has resulted from igneous forces. This

[1] The origin of the Archean Igneous Rocks, by N. H. WINCHELL : Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299-310. Summarized JOUR. GEOL., Vol. VII, 1899, p. 194.

is accounted for by supposing a chain of active volcanoes to have existed where the Mesabi iron range is now found. These volcanoes yielded flows and ejectamenta to the adjacent waters which have been modified into the various phases of the iron formation now seen. This volcanic epoch may have a deep-seated connection with the Cabotian or lower division of the Keweenawan (described later).

Above the iron-bearing member is an impure dark colored limestone a few feet in thickness, not exceeding twenty. It extends apparently the whole length of the Mesabi range, but has been identified in two places only, Sec. 7, T. 58 N., R. 17 W., and doubtfully on the shores of Gunflint Lake. This limestone may be regarded as the basal horizon of the next overlying rock.

The black slate is probably several thousand feet in thickness and constitutes the bulk of the Animikie. In the neighborhood of Gunflint Lake it has been divided by Dr. Grant into a lower black slate division and an upper graywacke-slate division, both of which members are interleaved with diabase sills.

In the Indian reservation at Grand Portage and at various places along the Grand Portage trail is a graywacke, which is supposed to overlie the black slate member, but its extent and stratigraphical position have not been satisfactorily established.

The top of the Animikie has not been identified. The first recognizable datum plane after the close of the Animikie is the Puckwunge conglomerate, supposed to be the fragmental base of the Keeweenawan.

At one or two places southwestward from Birch Lake, and at Little Falls on the Mississippi River, and in Morrison county, the Animikie has been converted into a mica-schist.

The age of the Animikie is believed to be Lower Cambrian for the following reasons: It graduates upward into Upper Cambrian rocks as seen on the south side of Lake Superior. The derivation of the iron ores from a glauconitic green-sand indicates that large quantities of foraminiferal organisms once lived in the Animikie ocean, and Matthew has shown the existence of foraminiferal organisms associated with the iron ore in the St. Johns group of New Brunswick. Further the Animikie has a uniformly low dip, while the lower strata are all highly tilted. There must therefore have been a great lapse of time between the deposition of the two series.

The Keweenawan.—The Puckwunge conglomerate is taken to be

the *fragmental* base of the Keweenawan, although certain igneous rocks which antedate it and which perhaps are contemporaneous with the upper portions of the Animikie are also called Keweenawan. The conglomerate is found at Grand Portage Island, at Isle Royale, on the Baptism River, at Little Marais, on Manitou River, at the deep well at Short Line Park near Duluth, and at New Ulm.

Above this conglomerate are conglomerates and sandstones of Keweenawan age which are stratified with lavas of diabasic nature. Still higher up the eruptive rocks become less in quantity and the fragmental rock is a sandstone, known as the Hinckley sandstone, quarried in the gorge of the Kettle River in Pine county. This in turn grades up into typical Upper Cambrian sandstones of the St. Croix valley. The term Potsdam is restricted to the Puckwunge conglomerate and the hardened quartzites immediately overlying it, represented by the Sioux quartzite, the Baraboo and Barron county quartzites of Wisconsin, the quartzite at Grand Portage Island, and west of Grand Portage village, the New Ulm quartzite in Cottonwood county, and the quartzite in Pipestone county.

The igneous rocks of the Keweenawan vary in age from the late Animikie time to the top of the Keweenawan series. They are divided into two groups, the Cabotian or Lower Keweenawan, and the Manitou or Upper Keweenawan.

The Cabotian division includes gabbro and contemporaneous red rock and their surface lavas, and all other dikes and sills which are associated with, but younger than, the Animikie clastic rocks, and which are older than the Puckwunge conglomerate. The lower member of the Cabotian is the gabbro, which covers an enormous area. It extends on the east to East Greenwood Lake in T. 64, N., R. 2 E. On the north it is bounded by the Animikie strata of the Mesabi iron range. Its westernmost exposure is in the vicinity of Short Line Park, Duluth. The southern limit is irregular, swinging from East Greenwood Lake in a zigzag manner through T. 63 N., R. 1 W., T. 62 N., R. 2 W., T. 62 N., R. 4 W., T. 60 N., R. 6 W., T. 60 N., R. 7 W., T. 58 N., R. 10 W., and T. 55 N., R. 11 W., to Duluth.

Along the northern and northwestern side of the great gabbro mass, the gabbro is plainly intrusive on the older formations, Animikie and Keewatin.

From the northern border of the gabbro many sills offshoot and penetrate the Animikie strata parallel to the bedding. These are known as the Logan sills.

Near its contact with the underlying rocks, both the Animikie and Keewatin series, there are various altered rocks which can be connected in places with the gabbro and in places with the underlying rocks. To these altered rocks the term muscovadyte has been applied. It includes the various so-called peripheral phases of the gabbro.

On the southern and eastern border the gabbro is penetrated by and penetrates in a confused manner the red rock, with which it alternates both structurally and areally. It is believed to have resulted from the metamorphism by the gabbro of the Animikie, and perhaps earlier fragmentals.

As the granites of the Archean are believed to have resulted from the softening of acid fragmentals, so the gabbro may probably have been the result of the metamorphism or re-fusion of the Keewatin greenstones.

The anorthosite masses of the Beaver Bay diabase, supposed by Lawson to be of Archean age and to underlie unconformably the Beaver Bay diabase, are believed to represent segregation phases in the main gabbro flow, and to be the same as anorthosite masses in the gabbro proper to the west.

The Beaver Bay diabase is believed to represent the upper portion of the great gabbro flow, and to be due to the first and greatest movement of the gabbro toward Lake Superior. The Logan sills belong to this part of the gabbro flow.

The Manitou division of the Keweenawan includes the surface flows, sills, and dikes which accompanied and followed the Puckwunge conglomerate. These eruptives, with the clastics associated with them, do not have a thickness in Minnesota of more than 1000 feet. These lava sheets extend along the shore of Lake Superior from near Baptism River to near Grand Marais, except where replaced at intervals by the Beaver Bay diabase or some of the intersheeted fragmentals. They occur also in the neighborhood of Grand Portage Bay, but their extent here is not definitely known.

General.—The most important petrological conclusions determined from the examination of the Minnesota crystalline rocks, are three in number:

1. All the granites of the Archean can be explained on the assumption that they are intrusives representing the metamorphosed conditions of clastic rocks adjacent to the observed intrusions, rendered plastic by the force of dynamic metamorphism accompanied by moisture.

2. The basic Keweenawan gabbro and its derivatives are derived from the metamorphism and complete re-fusion of the Archean greenstones and their attendants.

3. The green-sand of the Mesabi iron-bearing formation appears to have resulted from a volcanic sand and the taconite itself from igneous forces.

Comment.—The three main petrological conclusions announced by Professor Winchell as the most important results of his final petrological work, summarized in the closing general paragraph, would be dissented from by most of the other geologists who have worked in this area.[1]

The Cambrian age of the Animikie strata has long been maintained by Professor Winchell, and above are summarized his arguments in support of this position. The first argument, that the Animikie grades into the Upper Cambrian rocks, is not in accord with the observations of most of the geologists above referred to. The second argument, based on the similarity of the unaltered green-sand in the Mesabi district with that in the Cambrian of the eastern United States, loses weight when we consider the fact that the similarity is not great, the differences being many and significant; and if the similarity were complete, the correlation would involve laying too much stress on lithological similarity of widely separated formations. Professor Winchell's latest conclusion, that the Mesabi green-sand is volcanic and not organic, while entirely dissented from by others who have studied this rock, in itself spoils his argument based on similarity. The third argument in favor of the Cambrian age of the Animikie, based on the extent of the unconformity beneath the Animikie, has little value when unsupported by the other lines of evidence. Professor Winchell's conclusion as to the Cambrian age of the Animikie strata is thus not adequately sustained by the reasons given. The view that the Animikie is Upper Huronian (pre-Cambrian) is the commonly accepted one. The evidence favoring this view is summarized by Van Hise.[2]

Further comment on the above work would require reference to the detailed observations made in northeastern Minnesota during the

[1] Some of these geologists are: R. D. Irving, C. R. Van Hise, J. Morgan Clements, W. S. Bayley, U. S. Grant, J. E. Spurr, A. H. Elftman, C. K. Leith.

[2] Correlation Bulletin, Archean and Algonkian, No. 86, U. S. Geol. Survey; Principles of Pre-Cambrian Geology, Sixteenth Annual Report, U. S. Geological Survey.

past four years by the Lake Superior Division of the United States Geological Survey.[1] The results of this work have not been published and any reference to the conclusions reached would be premature. In general it may be stated that now, as in the past, there is divergence in the conclusions reached by the Minnesota Survey and by the United States Geological Survey concerning the position and importance of the unconformities, correlation of series, and nomenclature.

C. K. LEITH.

The Norwegian Polar Expedition, 1893 to 1896. Scientific Results. Edited by FRIDTJOF NANSEN. Vol. I. Longmans, Green, & Co.

The object of the report of which this is the first volume is stated in the preface to be "to give in a series of separate memoirs a complete account of the scientific results of the Norwegian North Polar Expedition of 1893 to 1896." The first volume contains the following papers: "The Fram," 16 pp. with three plates; "The Jurassic Fauna of Cape Flora, Franz Josef Land," by J. F. Pompeckj, with a "Geological Sketch of Cape Flora and its Neighborhood," by Fridtjof Nansen, 147 pp. with three plates; "Fossil Plants from Franz Josef Land," by A. G. Nathorst, 26 pp. with two plates; "An Account of the Birds," by Collett and Nansen, 53 pp. with two plates; "Crustacea," by G. O. Sars, 137 pp. with thirty-six plates.

The fossil fauna brought back from Cape Flora was collected by Nansen during the period of his stay with Jackson at Elmwood, Cape Flora, Franz Josef Land. The collection was studied by J. F. Pompeckj, whose descriptions of the fossils constitute the second part of the volume. Collections from the same localities secured by the Jackson-Harmsworth expedition were examined and described by Mr. E. T. Newton, but the conclusions reached by Pompeckj and by Newton as to the age of the strata are somewhat at variance.

The condition of preservation of the fossils is poor, and many species, particularly of lamellibranchs, could not be identified even generically. The collection shows that a fauna of at least twenty-six different species occurs in the Jurassic sediments about Cape Flora.

[1] The reports on this area in preparation by the survey are: Lake Superior Iron Ores, to appear in the Twenty-first Annual Report; Monograph on the Vermilion Iron Bearing District of Minnesota, and Monograph on the Mesabi Iron District of Minnesota.

The collections of the Jackson-Harmsworth expedition from the same region only afforded fourteen species, and seventeen of the species studied by Pompeckj were not recorded by Newton. The fossils were found at five localities, and at three of these they were *in situ.* From the results of his study of the Jackson-Harmsworth collections, Newton concluded that the "Lower Oxfordian rocks," and probably the equivalent of the "British Kellaway rocks," are represented in the Jurassic strata underlying the basalt at Cape Flora. Pompeckj, however, was able to identify four horizons in a much more definite manner. The lowest of these is Bajocian, and probably the lower Bajocian; the second is Lower Callovian, the zone of *Macrocephalites macrocephalus;* the third is the Middle Callovian, the zone of *Cadoceras milaschewici;* and the fourth is Upper Callovian, the zone of *Quenstedtoceras lamberti.* The Bajocian fauna is apparently without analogy in the arctic region, but seems to show direct affinities with the central European Jura. The Callovian faunas are very near those of the Russian Callovian, and these two regions were probably in direct communication during that part of Jurassic time. It is worthy of note that there is hardly any likeness between the fauna of Cape Flora and that of Cape Stuart, East Greenland.

In the fossils, one rather striking feature is the paucity of gastropods, one species only having been found in the marine fauna, while cephalopods and lamellibranchs are relatively much more abundant. This general relation also holds for the arctic fauna of northern Europe.

The identification of these beds at Cape Flora gives the northernmost locality of Jurassic beds, since the latitude of Cape Flora is nearly 10° farther north than that of the next most northerly deposit of this age. These beds show that the Bajocian sea of north Europe extended far to the northward. Spitzbergen was probably not covered; neither was Novaja Semlja, and these two islands were probably connected with each other and with Europe. This land area may have been extended northward to Franz Josef Land. The sea seems to have lain north and west of this land. The Petchora Basin sea is conjectured to have extended north between Spitzbergen and Novaja Semlja, and to have been bounded on the north by land in the region of Franz Josef Land. Spitzbergen is conjectured to have been connected with the Franz Josef Land of the Callovian epoch. The Callovian sea is conjectured to have extended east to Alaska. Toward the

end of the Callovian epoch the sea receded to the southward from Franz Josef Land, while Spitzbergen and Novaja Semlja were partly submerged.

The main body of the sedimentary Jura of Cape Flora extends from sea level up to 575 feet. It is fossiliferous in horizons only. The Callovian part of the Jura extends from 370 feet to 575.

The fossil plants secured by Nansen, also from the region about Cape Flora, were placed in the hands of A. G. Nathorst, and his report upon them constitutes Part III of the volume. These plant remains are all fragmentary and very poorly preserved, so that in most instances no specific identification could be made. Out of the twenty-nine forms recognized, only two are specifically identified with certainty, though seven others are compared with described species. The conclusions reached by Nathorst as to the age of the plant-bearing deposit is that "it was formed toward the close of the Jurassic or commencement of the Cretaceous period, without our being able at present to settle which." The fossil plants occur in two beds which lie between certain of the seven extrusive basaltic flows.

The account of the birds is divided into four sections, the first treating of the journey along the north coast of Siberia; the second gives the observations made while the "Fram" was drifting with the ice before Nansen left it; the third gives the observations made during the sledge journey of Nansen and Johansen; while the fourth gives the observations made on the "Fram" after Nansen left it in March 1895. This section of the report is a technical description of the species of birds seen.

The section on the Crustacea is in much detail and will be of great interest and value to zoölogists. The conclusion is reached that the bulk of the pelagic animals found in the North Polar basin were derived from the west through the Atlantic current flowing in beneath the superficial Siberian current. It has also been found that forms which have hitherto been regarded as quite southern in distribution are found in the polar sea.

The volume also makes some announcement of the contents of future volumes of the report. The second volume is announced to contain "The Astronomical Observations and their Results," "Terrestrial Magnetism," and "Pendulum Observations and their Results." The third volume will deal with "The Oceanography of the North Polar Basin," "Hydrometers and their Errors, especially those caused

by the Variation of the Surface Tension of Liquids," "The Depths and Submarine Features of the North Polar Basin, with chemical Analyses and Microscopical Composition of the Deep Sea Deposits," "Diatomaceæ and Algæ living on the Drifting Ice and in the Sea of the North Polar Basin." Many other memoirs are announced for still later volumes. It is stated that the number of volumes will probably be five or six, which it is hoped may be finished in the course of about two years. These volumes will not only furnish a large body of information about a little-known region, but some of them will deal with questions of world-wide application. The reports are to be issued in the English language only.

R. D. S.

The Pleistocene Geology of the South Central Sierra Nevada, with especial reference to the Origin of the Yosemite Valley. By Henry Ward Turner. Proceedings of the California Academy of Sciences. Third Series, Vol. I, No. 9; 9 Plates; pp. 361–321.

This paper gives a brief outline of the pre-Pleistocene orogenic history of the Sierra Nevada, the orogenic movements of the Pleistocene, and a brief sketch of the Pleistocene history of the region, as an introduction to the discussion of the origin of the Yosemite Valley. The Sierran period, the period of high lands preceding glaciation, is included in the Pleistocene. Some brief notes on the glacial period are also given, and the conclusion reached that there were two periods of glaciation separated by an interval of deglaciation, though the evidence on this point is not looked upon as altogether conclusive. The assumption that in the interior of the continent there were two (and not more) well-marked glacial epochs, needs to be modified in the light of the investigations of the last few years. The brief statement concerning the cause of the glacial period, also seems not to take account of the latest and most satisfactory views on this subject.

The several hypotheses which have been advanced concerning the origin of the Yosemite are considered, and the conclusion reached that this valley was not scooped out by the ice (Muir); that it is not a river-cut canyon, the walls of which were made vertical by the sapping action of ice (Johnson); and that there is no adequate evidence that it is due to a drop fault (Whitney, *et. al.*); but that it owes its origin to river

erosion influenced, in its topographic results, by the strong jointing of the rock of the region. This view, however, does not preclude the glaciation of the valley, but ascribes to the ice a very insignificant part in its excavation. R. D. S.

A Record of the Geology of Texas for the Decade ending December 31, 1896. By FREDERIC W. SIMONDS, PH.D. Reprint from Vol. III of the *Transactions of the Texas Academy of Science.* [Austin ?], August, 1900, pp. 280.

In 1887 the U. S. Geological Survey published Bulletin No. 45, by Professor R. T. Hill, upon "The Present Condition of Knowledge of the Geology of Texas." Although that bulletin was not a bibliography in the ordinary meaning of the word, it mentioned the chief publications upon the geology of the State of Texas up to 1886, and gave the general results of the work of the authors. The present volume by Dr. Simonds is an annotated bibliography covering the succeeding ten years. That particular decade has been the most fruitful period in the history of geological investigation in the State of Texas, and, as a consequence, Dr. Simonds' list is the most important one that could have been made of any limited period.

No one who has attempted a piece of bibliography will fail to appreciate this valuable contribution to geologic literature. Such publications represent a great deal of dead-work, much of it of a dreary kind. But Professor Simonds has rendered a genuine service both to the people of Texas and to the science of geology by bringing these titles together and giving a résumé of the contents of each paper. As a rule but few persons know just what has been published upon the geology of a given state, or where to lay hands upon it. This list fills the want, so far as Texas is concerned during the period 1886–1896.

The titles are arranged according to the alphabetic order of the authors, and there is an index of both authors and subjects at the end of the volume.

J. C. BRANNER.

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ON THE ORIGIN OF THE PHENOCRYSTS IN THE PORPHYRITIC GRANITES OF GEORGIA[1]

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INTRODUCTION.[2]

UNTIL quite recently, the idea has been prevalent among petrographers, that porphyritically developed minerals (pheno-

[1] Published by permission of the State Geologist of Georgia.

[2] The writer wishes to acknowledge his indebtedness to Professor A. C. Gill, of Cornell University, for kindly reading and criticising this paper in manuscript.

crysts) in intrusive igneous rocks were of intratelluric[1] origin. Indeed, as pointed out by Pirsson, no sharp distinction heretofore has apparently been drawn in the literature, between the origin of phenocrysts in intrusive and extrusive igneous rocks; indicating probably, that the porphyritically developed mineral or minerals were of the same origin in the two rock divisions here designated, and were formed at much greater depths than the place in which they are now found. The idea that phenocrysts in intrusive igneous rocks are not always of intratelluric origin, but have, in many cases, been formed *in place*, and are therefore contemporaneous in origin, with a part at least, of the other rock constituents, was advocated by Zirkel[2] in 1893; by Cross[3] in 1895; and more recently by Pirsson[4] and Crosby.[5]

Pirsson and Crosby are agreed in dissenting from the old and long-accepted theory, that appreciable or abrupt changes in the ratio of cooling and the viscosity of the magma, are essential elements in the development of the porphyritic structure — phenocrysts and groundmass — in intrusive igneous rocks.

A careful field study of the granitic rocks of Georgia, by the writer, during the seasons of 1898, 1899 and 1900, shows a number of extensive areas of coarse-grained porphyritic granites occurring within the limits of the Georgia Piedmont plateau. The distribution of the porphyritic granite areas is given on the accompanying map. The interior gradation or passage of the porphyritic facies, peripherally, into an even-grained coarse-textured non-porphyritic granite of the same mineral and chemical composition, is readily traceable in most of the granite areas.

[1] The term "intratelluric" is here used in the same sense as that given it by Pirsson in the Amer. Jour. Science, 1899, Vol. VII, p. 272, "meaning an earlier period and greater depth of the magma than that in which it came to rest."

[2] Lehrbuch der Petrographie, 1893, Vol. I, p. 737 et seq.

[3] Laccolitic Mountain Groups, U. S. Geol. Surv., Fourteenth Annual Report, 1895, p. 231.

[4] On the Phenocrysts of Intrusive Igneous Rocks, Amer. Jour. Science, 1899, Vol. VII, pp. 271–280.

[5] On the Origin of Phenocrysts and the Development of the Porphyritic Texture in Igneous Rocks, Amer. Geol. 1900, Vol. XXV, pp. 299–310.

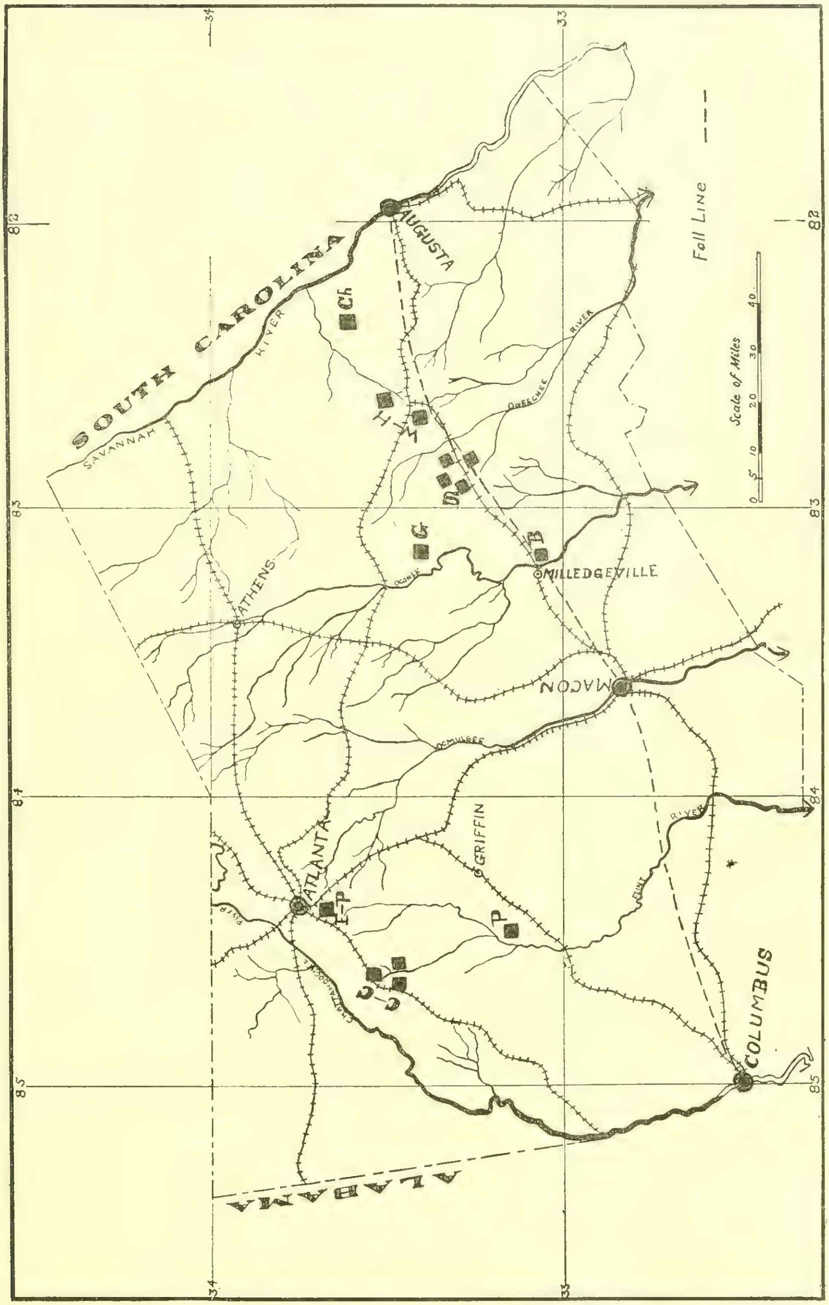

FIG. 1.—Map of Piedmont, Georgia, showing distribution of porphyritic granite described in the text.

The size, development and character of the phenocrysts in the porphyritic portions of the areas; and the gradation from one rock facies into another of the same composition shown in the same rock-mass, unquestionably point to contemporaneous growth with the groundmass constituents, and have, therefore, been formed *in place* and not at greater depths—intratelluric. In the present paper, it is proposed, therefore, to give a brief description and summary of the individual porphyritic granite areas; and to state the reasons for the belief in the contemporaneous origin of the phenocrysts with the groundmass constituents, based on a careful field and laboratory study of these rocks.

DESCRIPTION OF INDIVIDUAL AREAS

The Fayette-Campbell-Coweta counties porphyritic granite area.[1]—This area, marked C–C on the accompanying map, is thirty miles southwest from Atlanta and occupies contiguous portions of Campbell, Coweta and Fayette counties. The rock-outcrops are usually small and in the nature of bowlder and flat-surface masses. The exposures are most numerous in the vicinity of Palmetto and Coweta Stations on the Atlanta and West Point railroad, and near Line Creek in Fayette county. Specimens of the porphyritic rock collected from the outcrop near Line Creek in Fayette county are somewhat lighter in color than similar ones from the Palmetto-Coweta portions of the massif. The ratio of quartz to biotite in the Line Creek outcrop is visibly greater than in the Campbell-Coweta exposures, as indicated in analyses II and XI, p. 119. The rock, however, is generally quite uniform over the entire area. Several good contacts of the partially decayed porphyritic granite and mica-schist are exposed along the wagon roads and in the cuts of the railroad, traversing the area. The field relationships of the two rocks indicate, that the porphyritic granite is the younger rock; intruded into the overlying schist, and exposed subsequently by erosion.

The rock is a very coarse-grained porphyritic-biotite granite

[1] Eighteenth Annual Report, U. S. Geol. Surv., 1898, pp. 551–572.

of a medium, light to dark gray in color, according to the amount of biotite present. The extreme coarseness of texture renders the porphyritic structure less typically marked in this than in finer grained porphyritic rocks. The porphyritically developed mineral (feldspar) grades imperceptibly from very large, irregular, sometimes stout, tabular phenocrysts, into the smaller feldspars, making it difficult usually to distinguish between groundmass and phenocryst feldspars, except in extreme cases.

The feldspar phenocrysts vary from extremely irregular cleavable grains, anhedra, 30 by 30^{mm} to roughly idiomorphic crystals; tabular, parallel to the clinopinacoid (010), and twinned according to the Carlsbad law. Abundant inclusions of large irregular plates of biotite are readily visible in all the phenocrysts to the unaided eye. The phenocrysts are prevailingly allotriomorphic in outline and differ in this respect from those of the other areas described below. The feldspars are white in color, usually partially cloudy or opaque rather than limpid in appearance.

The biotite occurs as stout cleavable plates averaging 10–15^{mm} in size, occupying somewhat well-defined areas; is very dark in color, and highly lustrous. The quartz is present in large irregular colorless and smoky anheda, 4–5^{mm} in size, clearly outlined against the feldspar and biotite, from which it is readily distinguished.

Microscopic study of thin sections of the porphyritic granite confirms the macroscopic description, in affording no marked differentiation between groundmass feldspar and a part of the similar porphyritic constituent, or phenocryst.

The feldspar constituent is composed of the potash varieties, orthoclase and microcline, and a fair proportion of an acid plagioclase, which from its optical properties is near oligoclase. The presence of considerable lime in the analysis tends to corroborate this inference. The orthoclase usually shows good cleavage, and is separately intergrown with stringers of albite and quartz, in the form of microperthitic and micropegmatitic

structures. The potash feldspars and quartz of the groundmass are entirely allotriomorphic in crystal outline. The plagioclase feldspar occurs in roughly idiomorphic lath-shaped crystals characterized by the polysynthetic twinning, and, as a rule, afford very small extinction angles in basal sections.

The porphyritically developed minerals (phenocrysts) are composed of both orthoclase with numerous microperthitic structures, and microcline, usually inclosing inequidimensional anhedra of quartz, feldspar and biotite without definite optical orientation. The more basic inclusions, accessory apatite and zircon are also included in the phenocrysts.

A thin section of one of the feldspar phenocrysts from the Coweta portion of the area, shows the characteristic microcline structure, and contains abundant inclusions of irregularly bounded crystals of feldspar, quartz and biotite; several rounded disks or ovals of micropegmatitic intergrowths of quartz and feldspar, and prismatic needle-like inclusions of apatite and zircon (see Fig. 2.) A chemical analysis of fragments of carefully selected phenocrysts from hand specimens of the Coweta outcrops of the rock is given in XI a, page 119.

The biotite occurs as aggregated intergrown shreds with deep brown color, good basal cleavage and strong absorption, partially altered to chlorite and some epidote. The biotite is intergrown with occasional foils of muscovite, and sometimes shows good crystallographic boundaries. In addition to these, prismatic inclusions of apatite and zircon and a few grains of magnetite are present. The effects of dynamo-metamorphism are generally indicated to some degree in the rock by numerous fracture-lines and undulatory extinction common to the larger quartz and feldspar individuals.

Cubes[1] from the Rockingham, Richmond county, and Mt. Monroe, Iredell county, granite areas in North Carolina, very closely resemble in color, grain and texture the Campbell-Coweta-Fayette counties porphyritic granite, in Georgia. The

[1] Through the kindness of Dr. George P. Merrill, Head Curator, Department of Geology, U. S. National Museum, the writer was accorded access to the Tenth Census Collections of Building Stones in the Museum.

phenocrysts in the Carolina rock are usually allotriomorphic, occasionally idiomorphic, in crystal outline; and, as a rule, are large in size, and contain numerous plates of included biotite. A similar though darker colored rock, owing to a greater amount of biotite present, occurs in Aiken county, South Carolina. The

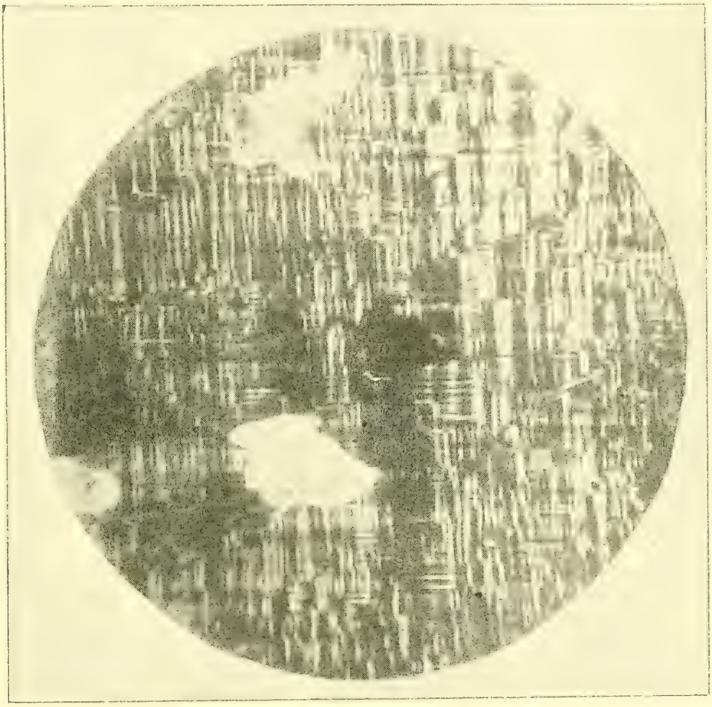

Fig. 2.—Photomicrograph of a phenocryst of microcline from the Coweta county porphyritic granite area, showing inclusions of quartz, plagioclase and biotite. The inclusions of plagioclase and biotite are considerably altered. Crossed nicols. Magnified 74 diameters.

porphyritic feldspars in the Aiken rock present the same characteristics as the phenocrysts of the Georgia and North Carolina porphyritic granites.

The Hancock county porphyritic granite area.—A coarse-grained porphyritic granite outcrops one quarter of a mile east of Sparta

depot, with the exposures more or less continuous from this point, for eleven miles, in a northeastwardly direction, along the Georgia railroad. The area lies near the merging of the crystalline rocks beneath the Coastal Plain sands and clays — the Fall-line (area marked S on the map). It is elliptical in shape with its longer diameter eleven miles in length, trending northeast-southwest. The granitic rock outcrops as bowlder and flat-surface masses, frequently containing four to five acres of exposed rock in one body.

The rock texture is prevailingly porphyritic, grading, in many cases, into a non-porphyritic, even-grained granite of the same mineral and chemical composition. In several quarries the rock shows in places a somewhat pronounced gneissoid structure. Some half dozen quarries have been extensively worked in various places over the area, within a few miles northeast of Sparta.

The rock is prevailingly a coarse-grained, medium gray, porphyritic biotite-granite. The phenocrysts are composed of the potash feldspars having a pronounced pinkish cast which disappears in thin section. They are flat tabular in crystal form, averaging 20^{mm} in length parallel to the clinopinacoid (010). Carlsbad twins of the contact type are common. The phenocrysts are further characterized by numerous inclusions of all the groundmass minerals.

The porphyritic feldspars are embedded in a coarse-grained groundmass of quartz, potash and soda-lime feldspars and biotite, with some accessory muscovite, chlorite, apatite, zircon, epidote and scattered grains of magnetite. Microperthitic structures are common to the potash feldspars. Micropegmatitic structures are less frequently observed, than in some of the other areas. The rock from the Sparta area differs from that of the Campbell-Coweta-Fayette counties area in containing less biotite, and hence, lighter in color; in the phenocrysts being idiomorphic instead of allotriomorphic in crystal outline, and usually of a pinkish cast rather than white in color. Microcline is, alike, variable for the two areas in thin sections of the rock examined from various

places. The relative proportion of the component minerals is, including all species present, feldspar > quartz > biotite.

Like the former area, the Sparta porphyritic granite is surrounded on all sides by mica-schist; but the great depth of residual decay of the granite and schist, renders exposures of the contact between the two impossible. The field relationships however, indicate, as in the above area, that the granite is the younger rock, intrusive into the then overlying schist.

The Baldwin county porphyritic granite area.—Large bowlder outcrops of a coarse-grained porphyritic granite occur three miles southeast from Milledgeville, the county seat of Baldwin. Like the Sparta area, the Baldwin county porphyritic granite mass is located near the line of contact (Fall-line) between the Piedmont crystallines and the Coastal Plain sediments (area marked B on the map).

Hand specimens of the granite from Baldwin county are indistinguishable from similar specimens of the Columbia county porphyritic mass, described below. The rock is a very coarse-grained porphyritic granite, composed of an aggregate of interlocking quartz and feldspars — orthoclase with microperthitic structures, microcline and plagioclase — with intergrown shreds of biotite. The rock varies in color from medium to dark gray. Both microcline and orthoclase occur in the groundmass and as porphyritically developed minerals. The phenocrysts measure in extreme cases 30–40^{mm} long and 5–10^{mm} broad. They are prevailingly idiomorphic in form; flat, tabular parallel to the clinopinacoid (010), and commonly twinned according to the Carlsbad law. Abundant inclusions of black biotite foliae are plainly visible to the unaided eye in the feldspar phenocrysts; while the microscope shows additional numerous irregularly bounded quartz and feldspar grains without definite orientation.

The groundmass is composed of an abundance of white opaque feldspars, slightly dark-colored smoky quartz, and biotite plates measuring 2–5^{mm} in diameter. The microscopic accessories are primary inclusions of apatite and zircon and scattered grains of magnetite, with some secondary muscovite, chlorite

and epidote derived from the alteration of the feldspars and biotite. Bent and curved filaments of rutile are quite abundant as inclusions in the larger quartz crystals. The effects of slight pressure metamorphism are evident in the lines of fracture and undulous extinction common to the larger quartz and feldspar individuals.

The Warren county porphyritic granite area.—Two somewhat extensive outcrops of foliated porphyritic granite occur in the middle eastern portion of Warren county, approximately ten miles from each other, in an almost east and west direction. These are known as the Holder's-Mill and Brinkley-Place granite masses, respectively, and marked W–H on the map.

The rock has a pronounced secondary foliated structure. The quartz and feldspar crystals are drawn out and inclosed between the biotite layers, forming at times distinct "augen" of the two light-colored minerals. The rock contains abundant black biotite plates arranged along somewhat parallel lines. The quartz and feldspar grains are greatly squeezed and mashed, and are more or less drawn out in directions parallel with the biotite layers, as a result of metamorphic action. The porphyritic granite of this area owes its foliated structure, therefore, to pressure metamorphism,[1] so common to many igneous rock masses in those regions subjected to mountain-building forces. Hence it is derived or secondary and not primary or fluidal.

The feldspar phenocrysts are composed principally of microperthitic orthoclase with some microcline $15–20^{mm}$ long; are white opaque to pink in color; contain numerous inclusions of biotite plates, and exhibit the usual habit of Carlsbad twins. They are prevailingly irregular in crystal outline and badly fractured from subsequent intense metamorphism. The porphyritic feldspars are embedded in a coarse-grained groundmass of quartz, feldspar and biotite. The groundmass feldspathic constituent consists of the potash feldspars with microperthitic structures, and

[1] Gregory has established, according to origin, three classes of gneisses, namely, metapyrigen-gneisses, clastic-gneisses, and fluxion-gneisses. See Quart. Jour. Geol. Soc. (London), 1894, p, 266; DALY, R. A. JOUR. GEOL. (Chicago), Vol. V, p. 780.

some laths of plagioclase near oligoclase. The large feldspar individuals (phenocrysts) contain inclusions of irregularly bounded crystals of quartz, biotite and other feldspar species. These inclusions are usually round, oval shape in outline. The quartz and feldspar anhedra are variously interlocked as fine and coarse-grained mosaics. The finer-grained mosaics of the two minerals

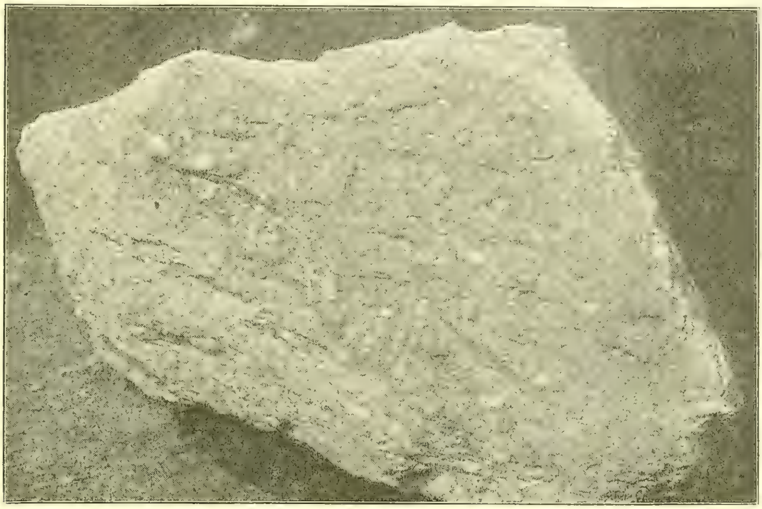

FIG. 3.—The Virginia type of foliated porphyritic granite near Chatham, Va.

represent the peripheral shattered portions of the larger feldspar and quartz crystals. Micropegmatitic structures, intergrowths of quartz and feldspar, are very common. Biotite occurs as grouped shreds and plates, deep brown to occasional green in color, with strong absorption and good basal cleavage. It is partially altered to a dark opaque chlorite and occasional crystals of slightly pleochroic and strongly double refracting epidote. A few scattered grains of magnetite are observed.

An outcrop, from which some rock has been quarried, of a similar dark-colored, foliated biotite porphyritic granite is found near Chatham depot, Pittsylvania county, Virginia. The feldspar phenocrysts are very large in size, 40–50^{mm} long, roughly

tabular in outline and twinned according to the Carlsbad law, and shows an abundance of large included biotite shreds (see Fig. 3).

Still a third exposure of granitoid rock showing a pronounced porphyritic texture in places, occurs six to eight miles south of the Holder's Mill-Brinkley Place area. It differs quite strongly from the Holder's Mill-Brinkley Place granite in the porphyritic texture being less strongly marked and finer grained; in containing less biotite, and is massive instead of foliated in structure. It further differs from the former area in containing a larger proportion of plagioclase, and a smaller percentage of microcline feldspars. Only one included grain of microcline was found in a number of thin sections studied of this rock. The feldspar phenocrysts are deep pink in color, 5–10^{mm} long, displaying the usual characteristic twinning and cleavage; and carry numerous inclusions of all the groundmass minerals.

The Greene county porphyritic granite area.—The Greene county porphyritic granite area, marked G on the accompanying map, includes at least 100 acres in the main granite outcrop, located ten miles south of Greensboro, in the southern part of the county. The main central exposure is in the form of a low flat doming-mass with a roughened and irregular surface, and partially covered, in places, with a thick growth of cedars (see Fig. 4).

An even granular medium coarse-grained granite outcrops in bowlder form three miles south of Greensboro, and is continuous along the public highway from this point to the main porphyritic granite mass (see Fig. 5). The true granitic facies of the rock mass grades interiorly into the typical porphyritic granite facies. The even-grained granitic portion of the mass representing the outer or peripheral zone, indicates some variation in mineral composition, from place to place, along a north and south section. The zone nearest the porphyritic area, two and one half miles north therefrom, and showing absence of all trace of porphyritic texture, is a medium-grained biotite granite agreeing, microscopically, in mineral composition, and in chemical composition as well, with the porphyritic granite.

Five miles north of the central porphyritic mass are outcrops of a coarse but close compact-grained granite, containing only a very small amount of biotite. The feldspars show pronounced pink and greenish tints.

About four miles south of Greensboro, on the north side of Beaver-Dam Creek, is an outcrop of practically the same granite. The quartz is decidedly dark in color and of the smoky variety;

FIG. 4.—The Greene county porphyritic granite area.

the feldspars are flesh colored, and the rock contains but little mica.

The porphyritic facies of the rock consists of a coarse-grained, light-gray groundmass of quartz, feldspar and biotite, in which are embedded large, flat tabular feldspar phenocrysts. The porphyritic feldspars average 30–50^{mm} long and 10–15^{mm} broad; and indicate the usual elongation parallel to the clinopinacoid (010), and Carlsbad twinning. The phenocrysts are deep pink to perfectly white in color, and are usually cloudy and opaque in appearance.

A thin section of one of the phenocrysts under the microscope showed the feldspar variety, microperthitic orthoclase. The microscope further showed abundant inclusions of fairly large crystals of feldspar, twinned, in several cases, after the albite and Carlsbad laws; and allotriomorphic crystals of quartz and biotite with partial orientation with the (010) cleavage.

FIG. 5.—Bowlder outcrops of granite near central mass of the Greene county porphyritic granite area.

(Fig. 6.) As a rule, however, the inclusions show no definite orientation. The biotite inclusions are always sufficiently large to be visible to the unaided eye.

The ratio of phenocryst to groundmass is quite variable; the probable extremes being represented by the following estimated ratios; 1 : 1 and 2 : 1, with all gradations between. The individual mineral grains vary from a few millimeters to 5 and 6^{mm} in size. The arrangement of phenocrysts in occasional small portions of the mass is suggestive of fluxion structure.

The potash feldspars, orthoclase and microcline, are the porphyritically developed minerals. The orthoclase contains

numerous microperthitic structures. Plagioclase is somewhat abundant. Small-rounded disks or ovals of micropegmatitic structures are common. The larger feldspar and quartz crystals indicate slight peripheral shattering in some of the thin sections.

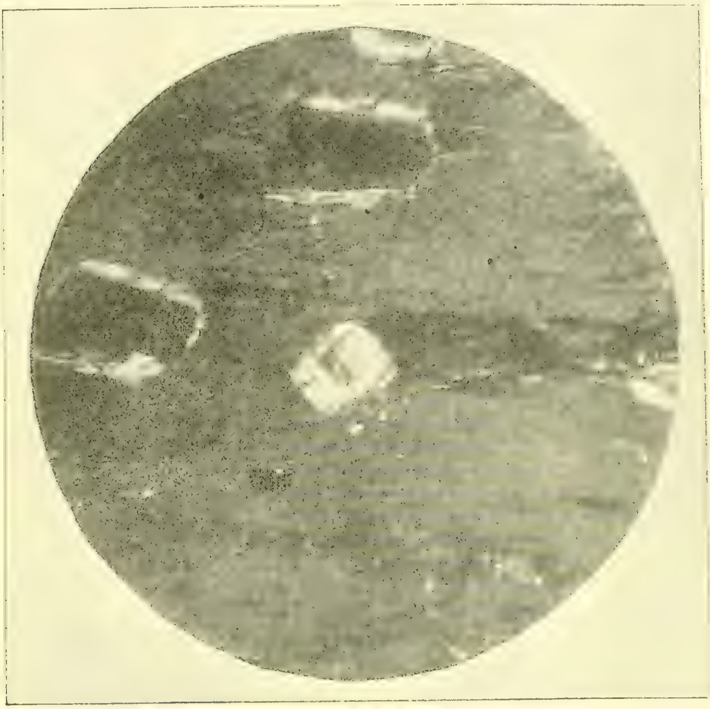

FIG. 6.—Photomicrograph of a phenocryst of microperthitic orthoclase from the Greene county porphyritic granite area, showing inclusions of quartz, plagioclase, biotite, and very small prisms of apatite. Crossed nicols. Magnified 74 diameters.

The biotite is considerably altered to chlorite and some epidote, and at times carries inclusions. Scattered grains of magnetite and prismatic inclusions of apatite and zircon are present in microscopic proportions.

The Columbia county porphyritic granite area—Heggie Rock.—This area, marked Ch on the accompanying map, is located near the Fall-line—contact between the Piedmont crystallines

and the Coastal Plain sediments—and a short distance west of the Carolina line.

One and three quarter miles east of Appling, the county seat of Columbia, is an outcrop of a coarse-grained porphyritic granite. The feldspars are slightly pink in color with a somewhat greenish cast in places. The phenocrysts measure $20–35^{mm}$ in length and $5–15^{mm}$ broad; and commonly show the contact type of Carlsbad twins.

Microscopically, the rock is composed of a coarse-grained groundmass of potash and plagioclase feldspars, orthoclase predominating, and quartz with biotite and occasional large plates of muscovite. The phenocrysts are large tabular microperthitic orthoclases. The anhedra of quartz vary in size and are badly fractured. Laths of polysynthetically twinned plagioclase are more abundant in this than in many of the other areas. Pegmatitic intergrowths of quartz and feldspar are sparingly present. The large feldspar phenocrysts contain abundant inclusions of the groundmass minerals, especially biotite and plagioclase.

The main porphyritic granite mass is one and one quarter miles further east. The rock outcrops as a large doming-mass. The porphyritic facies of the granite-mass is readily traceable peripherally into an even granular medium coarse-textured granite. The even granular facies of the rock mass is best exposed along the public highway three miles slightly east of south from Appling. Hand specimens of the rock from the two exposures cannot be distinguished from each other. The porphyritic feldspars in the principal exposure are larger but show the same idiomorphic and other microscopic tendencies, developed in the smaller one.

A thin section of one of the phenocrysts from the main outcrop showed the characteristic microcline structure, with numerous inclusions of irregularly bounded crystals of all the groundmass minerals. A chemical analysis of carefully selected fragments of phenocrysts from this rock, yielded the writer the results given in IVa, page 119.

The phenocrysts are embedded in a close and firm, but

coarse-grained groundmass of flesh-colored feldspars tinged a slight greenish cast, somewhat dark smoky quartz, and biotite. The porphyritic feldspar crystals make up nearly one half of the total rock. The feldspars are white and opaque rather than pink in color over the greater part of the exposure. This rock very closely resembles that from Greene county in the hand specimens. Here, as in the areas described above, the feldspathic constituent consists of the potash and soda-lime feldspars, with the potash varieties predominating. The porphyritic feldspars are chiefly orthoclase with some microcline, carrying inclusions of all the groundmass minerals. The included biotite shreds are visible macroscopically. Some of the largest plagioclase inclusions in the orthoclase phenocrysts carry, in turn, microscopic inclusions of quartz and other groundmass minerals. Twinning according to the Carlsbad and albite laws among the included feldspar species is commonly observed.

Biotite shows its usual characteristic optical properties, and is partially altered to chlorite and epidote. Muscovite is sparingly present as foils intergrown with the biotite. Sporadic accessory magnetite and apatite occur.

The Pike county granite area.—The Pike county granite area, marked P on the accompanying map, includes fifty or more acres of exposed flat-surface rock in the northwest part of the county. The porphyritic facies of the rock gradually passes into the even-textured medium-grained granite. Only a small proportion of this area, however, shows the porphyritic texture.

The rock is a medium-grained biotite granite, varying from even granular to porphyritic in texture, showing a partial gneissoid structure in places.

Microscopically, the porphyritic portions of the rock are composed of orthoclase phenocrysts in a coarse-grained groundmass of quartz, microperthitic orthoclase, microcline and some soda-lime feldspar, biotite, and occasional intergrown shreds of muscovite. Biotite is the chief accessory mineral. It is deep brown to yellow in color, with strong absorption, and is intergrown with some muscovite. It is more or less altered to dark

green opaque chlorite, and to a less degree, to a faint brown pleochroic epidote. Inclusions of prismatic apatite and zircon, and rounded disks or ovals of micropegmatitic structures are very common.

The phenocrysts consist of the potash feldspars, orthoclase and microcline, 10–30^{mm} long and 5–10^{mm} broad; tabular parallel to the clinopinacoid (010). Carlsbad twinning is common. Inclusions of biotite foliae equally as large as those occurring in the groundmass are very abundant in the phenocrysts. In addition to the biotite, they contain microscopic inclusions of irregularly bounded crystals of the interstitial quartz and feldspar.

The Fulton county porphyritic granite area.—The Fulton county porphyritic granite area, marked E–P on the accompanying map, is exposed in bowlder form over a large territory six miles south of Atlanta, in the extreme southern part of the county. The gradation from the interior porphyritic facies, peripherally, into an even-grained granite of the same color and texture, and having the same mineral and chemical composition, is more gradual and more strikingly shown in this than in any one of the previously described areas. Near the center of the granite mass the phenocrysts compose more than 50 per cent. of the entire rock, while near the transition zone—change of the porphyritic to the non-porphyritic texture—the phenocrysts are very sparingly present, not more than a half dozen are shown in a yard square of the rock surface. Near the center, the phenocrysts are prevailingly idiomorphic in crystal outline, while the allotriomorphic type of phenocryst characterizes the transition zone of the rock mass.

The rock consists of a medium coarse-grained groundmass of quartz, the potash feldspars, orthoclase and microcline, numerous laths of polysynthetically twinned plagioclase, biotite, and some muscovite, in which are embedded large potash feldspar phenocrysts. Accessory apatite, magnetite, and zircon; and the alteration products, muscovite, sericite, chlorite, and kaolin are noted. The microscope shows the feldspars and biotite to be considerably altered in some cases.

Microcline and orthoclase occur porphyritically developed, and measure 15 to 50^{mm} in length. The phenocrysts possessing idiomorphism usually display the Carlsbad habit of twinning, and are elongated in the clinopinacoidal direction.

A thin section of one of the phenocrysts showed the characteristic microcline structure and numerous inclusions of quartz, biotite, and the groundmass feldspars, which measure as much as one millimeter in size. Prismatic crystals of apatite and zircon, as inclusions in both the phenocryst and the included groundmass feldspars of the porphyritic crystal, are numerous. The zircon crystals are sometimes grouped in threes, much after the manner of penetration twins.

RÉSUMÉ

Since the individual areas have been described in some detail, it is important that a general summary of the essential features common to the several porphyritic granite masses be given. These can best be summarized under the two headings, *macro-* and *microscopic* features.

Macroscopic features.—The same textural and structural characteristics and relationships are generally developed in all the individual porphyritic granite areas. With the exception of the Warren (W–H) county area, the rocks are prevailingly massive, coarse-grained, porphyritic granites, varying, according to the proportion of biotite present, from dark to medium gray in color. The Warren county granite differs structurally from that of the other areas in possessing a marked foliated structure, resulting from dynamic metamorphism, which is accordingly secondary. Further evidence already mentioned of dynamic action in this rock mass is apparent microscopically. Evidence of a partial gneissoid structure is indicated in portions of several of the other areas, but, as a rule, the rock is generally massive.

Field study shows the development of the porphyritic texture in the interior of the rock masses, with the even-granular granitic facies having the same mineral and chemical composition forming the marginal or body portion. Gradation from

one rock facies into the other was not entirely clearly defined in all of the granite masses, owing to lack of exposures of the fresh rock, but could be easily traced in many. The feldspar phenocrysts are irregularly distributed through the coarse-grained groundmass without definite arrangement or orientation. The fluxion primary structure was not entirely evident in any one of the areas studied.

Microscopic features.—Microscopically, the rocks are as nearly identical as is possible for separate areas to be. They contain, in every case, the same minerals, both essential and accessory, in nearly the same proportions. They are composed of admixtures of the feldspars and quartz, in which lie stout plates of biotite. The relative amounts of the component minerals may be expressed as follows: feldspar, including all species present, >quartz>biotite. Biotite is the chief accessory and varies somewhat in quantity for the individual areas. In a number of the sections the biotite is intergrown with occasional foils of muscovite. The potash feldspar varieties of the groundmass predominate and are prevailingly allotriomorphic in crystal outline. Both orthoclase and microcline occur with the former in excess. The plagioclase crystals are roughly lath-shaped in outline, and, as a rule, afford small extinction angles in basal sections, which indicates an acid feldspar near oligoclase. The presence of considerable lime and soda in the analyses corroborates the inference. The orthoclase feldspar shows microperthitic intergrowths with a second feldspar, probably albite. In all the sections some of the feldspar crystals show a micropegmatitic intergrowth with quartz, which takes the form of rounded disks or ovals, and are not of the arborescent or radiate growth type.[1] There can be little doubt that this structure is primary in the porphyritic granites as a whole, affording evidence of simultaneous crystallization of the quartz and feldspar. The quartz occurs in irregular interstitial grains of varying size, and is very common in drop-like inclusions in the feldspars. Prismatic

[1] See ROMBERG in N. J. B. B.—B., 1892, Vol. VIII. MATHEWS, E. B.: JOUR. GEOL., 1900, Vol. VIII, p. 231.

inclusions of apatite are the most common of the primary accessories. Some zircon and a very little magnetite occur. More or less chlorite, some epidote and muscovite are present as constant secondary products from the alteration of the biotite and feldspars. In many of the sections, the effects of pressure metamorphism are frequent in the nature of crushing, lines of fracture, and undulatory extinction common to some of the larger quartz and feldspar crystals.

The potash feldspars are the only porphyritically developed minerals. The phenocrysts vary from allotriomorphic to flat tabular idiomorphic crystals in outline, in which the (001) and (010) cleavages are usually well developed, and are elongated in the clinopinacoidal direction. The usual habit of the simple Carlsbad twins prevails. The idiomorphic type of phenocryst greatly predominates over the allotriomorphic form. As a rule, the phenocrysts are very conspicuous, and are readily differentiated from the groundmass feldspars; although in the Coweta-Campbell-Fayette counties area (C–C) the phenocrysts and a portion of the groundmass feldspars seemingly grade into each other. The phenocrysts invariably contain inclusions of a majority of the groundmass constituents, some of which are visible to the unaided eye. The inclusions are distributed, as a rule, through the rock without regard to any definite arrangement or orientation.

CHEMICAL COMPOSITION

The marked uniformity in the mineral composition of the various porphyritic granites from the individual areas, suggests similar uniformity in chemical composition. The usual amount of free quartz common to this class of rocks; the abundance of potash feldspar, with somewhat increased amounts of plagioclase and proportionally small amounts of accessory minerals, indicate a normal percentage of silica and lime, an increased percentage of alkalies, and comparatively small amounts of iron and magnesium oxides. These inferences are well shown in the following analyses, made by the writer, in the laboratory of the State Survey. Attention is called in the table of analyses to the

prevailingly high percentage of soda in all of the rocks described above. In nearly half of the analyses, the soda is slightly in excess of the potash, and in the remaining ones it nearly equals or is but slightly less than the potash. This high range in soda is traceable, first, to the prevalence of microperthitic intergrowths of albite with the potash feldspars; next, to the amount of soda-lime feldspar present in the rocks; and, lastly, to the potash being replaced, in part, by soda in the straight potash feldspar molecule (analyses IVa and XIa).

GENETIC RELATIONSHIP OF PHENOCRYST TO GROUNDMASS

Evidences of intratelluric origin.—The evidences upon which the formation of phenocrysts at great depths and under conditions different from those of the groundmass constituents in igneous, intrusive rocks, rest have been adequately discussed by Pirsson[1] and are shown to be: (1) Contrast in size and crystal form of phenocryst to the groundmass constituents. (2) The fluidal arrangement, common in many cases, to the porphyritic minerals. (3) Irregularity of form, traceable to corrosion or resorption of the crystal (phenocryst) by the magma.[2]

These will be discussed in relation to the phenocrysts of the Georgia porphyritic granites under the next heading.

Evidences of contemporaneous origin.—The evidences favoring contemporaneous origin of the phenocrysts in the Georgia porphyritic granites may, for convenience, be discussed under (1) megascopic proofs: geologic or field observations; and (2) microscopic proofs: study of the thin sections of the rocks.

Both the macro- and microscopic characteristics of the Georgia porphyritic granites have been described in considerable detail under the individual areas above. Hence it is only necessary here to summarize and classify the facts pointing to a contemporaneous origin for the phenocrysts.

[1] Amer. Journ. Sci., 1899, Vol. VII, p. 278.

[2] IDDINGS, J. P.: Bulletin, Phil. Soc. of Washington, 1889, Vol. XI, p. 77.

TABLE OF CHEMICAL ANALYSES

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	IVa	XIa
SiO_2	70.90 1.181	70.88 1.181	70.24 1.170	69.77 1.162	69.48 1.158	69.37 1.157	69.17 1.152	69.13 1.152	67.62 1.127	66.31 1.105	63.65 1.060	64.64	64.40
Al_2O_3	15.86 .155	15.86 .155	16.78 .164	17.05 .167	16.64 .163	16.99 .166	16.47 .163	17.14 .168	16.29 .159	18.27 .179	20.46 .200	19.64	18.97
Fe_2O_3*	1.37 .008	1.77 .011	1.46 .009	1.60 .010	1.84 .011	1.99 .012	1.23 .007	1.52 .009	2.31 .014	2.51 .015	2.20 .013	0.37	0.37
CaO	2.15 .038	1.79 .032	2.00 .035	2.21 .039	2.32 .041	2.03 .036	2.02 .036	1.85 .033	2.37 .042	2.91 .052	3.28 .058	0.67	0.59
MgO	0.02 .001	0.93 .023	0.76 .019	0.99 .024	0.29 .007	0.84 .021	0.61 .015	0.79 .019	0.78 .019	1.22 .030	1.50 .037	tr.	tr.
K_2O	4.62 .049	4.64 .049	5.03 .053	4.08 .043	4.49 .047	4.54 .048	4.41 .047	5.49 .058	4.58 .048	4.09 .043	4.58 .048	10.00	11.40
Na_2O	5.05 .081	3.94 .063	3.70 .059	3.97 .064	4.74 .076	3.44 .055	4.89 .078	4.06 .065	5.42 .090	3.69 .059	4.75 .076	3.06	3.60
Igni	0.50	0.49	0.50	0.44	0.46	0.55	1.06	0.52	0.32	0.62	0.42	0.22	0.19
Total	100.47	100.30	100.47	100.11	100.26	99.75	99.85	100.50	99.69	99.61	100.84	98.60	99.52

* All iron was determined as Fe_2O_3.

I. Georgia Quincy Granite Company's Quarry, near Sparta, Hancock county.
II. A. J. McElwaney's place, near Line Creek, Fayette county.
III. Flat (Cedar) Rock, 9 miles west of Zebulon, Pike county.
IV. Heggie-Rock, 3 miles east of Appling, Columbia county.
V. Sparta Quarry, Hancock county,
VI. Mrs. L. N. Calloway's place, 3 miles southeast from Milledgeville, Baldwin county.
VII. The Moseley Quarry, 6 miles south of Atlanta, Fulton county.
VIII. Porphyritic granite area, 10 miles south of Greensboro, Greene county.
IX. The Charley Rocker Quarry, near Sparta, Hancock county.
X. Brinkley place, near Camak, Warren county.
XI. The J. R. McCollum place, near Coweta Station, Coweta county.
IVa. Feldspar phenocrysts from Heggie-Rock, Coumbia county.
XIa. Feldspar phenocrysts from the J. R. McCollum place, Coweta county.

The field observations include (1) passage or gradation interiorly from the porphyritic facies, peripherally into an even-granular, coarse-textured granite of the same mineral and chemical composition. The peripheral or border zones of the porphyritic granite masses, representing the granular facies of the rock, generally attain considerable widths in the Georgia areas, from which phenocrysts are entirely absent. (2) The general absence of definite (fluidal) arrangement or orientation of the phenocrysts in the groundmass. The Greene county porphyritic granite mass possibly affords, in places, the faintest possible evidence of the tabular phenocrysts having moved in a liquid magma, with partial definite arrangement or orientation. If these special parts of the area be accepted as indicative of flow structure, however, then we must also grant the contemporaneity in crystallization of the groundmass constituents for the same portions of the mass; for all of the other constituents, particularly biotite, are abundantly included in the phenocrysts of all parts of the area. The included biotite plates are equally as large as the same constituent in the groundmass. The other inclusions are microscopic in size and proportions.

The Brinkley-Place Holder's-Mill porphyritic granite has a pronounced foliated structure. This structure resembles in certain particulars, in places, the fluxion structure of some rocks, but in this case the foliation is shown to be secondary or derived — induced — and not primary or fluidal.

The phenocrysts are badly fractured and drawn out as "augen" between the inclosing groundmass minerals, roughly parallel in the direction of their longer diameters. Furthermore, the microscope indicates abundant squeezing and mashing and peripheral shattering of the quartz and feldspars, so characteristic of a secondary structure resulting from dynamometamorphism.

The microscopic evidence, favoring contemporaneous origin of the phenocrysts with the groundmass constituents, is chiefly that of prevailing abundance of all the groundmass minerals, as inclusions in the phenocrysts, for the areas studied. In every

case the biotite inclusions are readily distinguished megascopically.

The comparative abundance of inclusions[1] in the phenocrysts, and the form and size of the latter, suggest a rapid growth for the porphyritic crystals. The inclusions are not limited to and distributed through the outer zones of the phenocrysts, indicative of different periods in crystal growth with reference to the groundmass constituents, but, on the contrary, they are scattered through all parts of the crystal (phenocryst). The inclusions are grouped, with few exceptions, without regard to crystallographic lines or directions, and without uniform orientation with reference to the host and each other. No external evidence in the nature of crowding and pushing aside of the adjacent groundmass microlites during the growth and expansion of the phenocrysts has been observed, resulting in some cases, as mentioned by Pirsson,[2] in the resemblance to the flow structure.

The microscope, as a rule, fails to indicate, in the rock sections studied, rounding or irregularity in crystal outline of the original phenocryst resulting from a partial resorption or corrosion of the crystals by the magma in the Georgia areas.

Phenocrysts of roughly idiomorphic outlines — flat, tabular- and irregular-allotriomorphic forms — appear, with the former predominating in most of the areas. In view of confirmatory evidence, elsewhere stated in this paper, idiomorphism among the phenocrysts in the Georgia rocks could in no-wise be accepted as resulting from formation at greater depths and under entirely different conditions from the other constituents. In the absence of all other evidence it would be difficult to prove that form alone was a definite criterion favoring intratelluric origin. Pirsson[3] has shown that contrast in crystal form and size may very well be explained in an entirely different way.

[1] *Ibid.*, p. 80. [2] Op. cit., pp. 276, 277.

[3] *Ibid.*, pp. 278–280; see also CROSBY, W. O.: Amer. Geol., 1900, Vol. XXV, pp. 299–310.

The absence of (a) definite arrangement or orientation among the phenocrysts; (b) of phenocrysts from the border zones of the massif — gradation from an interior porphyritic facies peripherally into an even-granular granite of coarse texture and the same mineral and chemical composition; (c) the further absence of evidence of magmatic resorption or corrosion of the phenocrysts; and (d) the presence of abundant inclusions of all the groundmass constituents, characterizing the generally tabular phenocrysts of the Georgia porphyritic granites, fully justify the conclusion that the phenocrysts in these rocks were formed *in place*, and are not intratelluric in origin.

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CERTAIN PECULIAR ESKERS AND ESKER LAKES OF NORTHEASTERN INDIANA

Northeastern Indiana is traversed by a series of massive moraines of late Wisconsin age, the joint product of the Erie and Saginaw lobes of the Laurentide ice-sheet. The Erie ice invaded the region from the south of east, the Saginaw ice from the east of north. Thus the general directions of ice movement in the two were at right angles to each other. The Saginaw lobe was relatively feeble and withdrew from the region before the Erie lobe. Along their line of contact there is much confusion, but it is possible to correlate the moraines and to mark out with considerable accuracy the limits of Erie and Saginaw drift.[1] The region abounds in unusual features. Half-filled valleys and abnormal drainage lines, isolated knobs and morainic outliers, clusters and chains of lakes, kettles, and kames conspire with esker-like ridges to produce a type of topography and scenery which seems artificial and almost bizarre. The southwestern portion of Noble county presents forms which are, perhaps, best described under the name of eskers.[2]

On the line between the townships of Noble and Washington a system of ridges occupies about two square miles and surrounds the basin of High Lake. The most prominent member is a gravel ridge one mile long, extending east and west along the south side of High Lake. It is highest and broadest at the east end, where it surrounds and encloses an oval kettle whose bottom is at lake level. The sides of the kettle rise to 25 and 35 feet at the lowest points, and to 70 and 85 feet at the highest points, which are at the ends of the oval. The westward extension of the ridge has a height varying mostly between 50

[1] Eighteenth Report Indiana Geology, pp. 28, 84.

[2] The data for the maps, Figs. 1 and 2, were obtained with an aneroid and tape line, township, section, and farm lines, and the surface of the principal lake in each being used as bases.

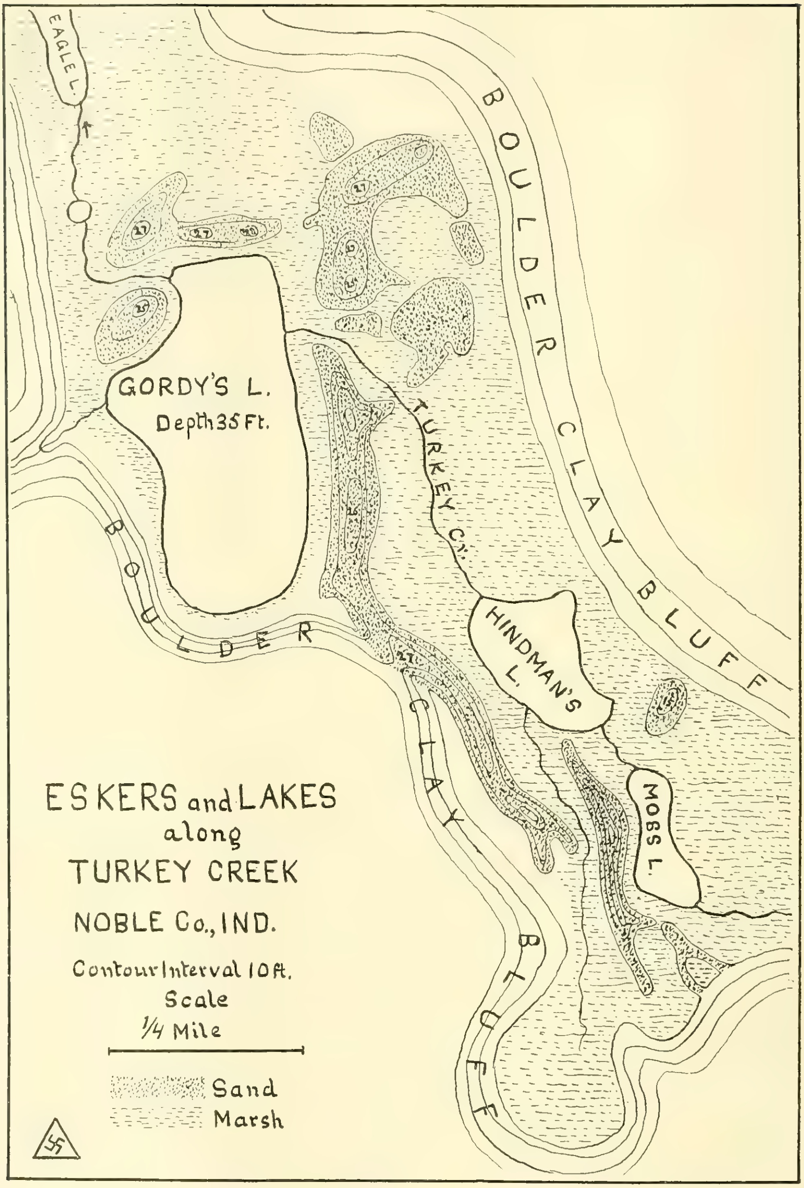
EAGLE L.
BOULDER CLAY BLUFF
GORDY'S L.
Depth 35 Ft.
TURKEY CR.
BOULDER CLAY BLUFF
HINDMAN'S L.
MOBS L.
ESKERS and LAKES
along
TURKEY CREEK
NOBLE Co., IND.
Contour Interval 10 ft.
Scale
1/4 Mile
Sand
Marsh

FIG. 1.

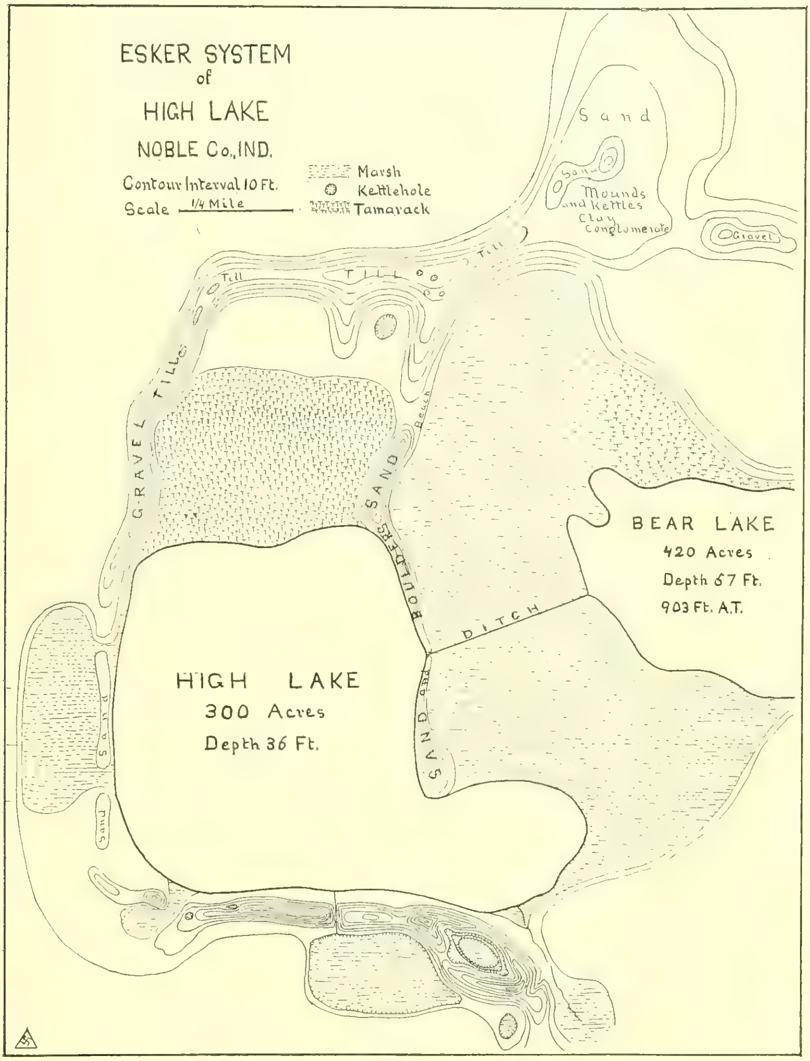
ESKER SYSTEM
of
HIGH LAKE
NOBLE Co., IND.
Contour Interval 10 Ft.
Scale 1/4 Mile
Marsh
Kettlehole
Tamarack
Sand
Mounds
and Kettles
Clay
Conglomerate
Gravel
Till
TILL
GRAVEL TILL
SAND
BOULDERS
Beach
DITCH
BEAR LAKE
420 Acres
Depth 67 Ft.
903 Ft. A.T.
HIGH LAKE
300 Acres
Depth 36 Ft.
Sand
SAND and SAND

FIG. 2.

and 75 feet, falling to 30 feet at one point where a ditch has been cut through it. The crest is usually sharp, and the lateral slopes are as steep as the material will permit. A small pit which has been opened on the southeast slope shows coarse rounded gravel without definite stratification. The ditch is cut through sand and fine gravel. At one point near the lake shore there is an outcrop of cemented gravel. These are the only exposures, and since the whole ridge is covered by a heavy growth of oak timber, investigation is difficult.

A mile and a half to the north the gravel ridge just described is paralleled by an equally massive ridge of till which rises 50 to 60 feet above lake level and 30 to 40 feet above the general level of the country. It is broad and flat-topped with steep and symmetrical slopes, and pitted with numerous small kettles. It extends westward three fourths of a mile and then, bending sharply to the west of south, is prolonged an equal distance in that direction to the northwest corner of High Lake. The southern half of this portion, however, is composed of gravel; the transition from till to gravel being abrupt and marked only by a slight change in the trend. The gap between the ends of the two gravel ridges above described is almost closed by a series of broken ridges of sand, generally less than ten feet high, but rising in one sharp peak to forty feet.

From the central mass of the till-ridge two short spurs project toward the south. One of these is separated by only a small gap from a ridge of sand which continues in the same direction to the northeast corner of High Lake and along its eastern border. On the north it is broad, rounded, and 40 feet high, but narrows and falls toward the south to a height of 5 feet, then widens and rises to 35 feet at the southern end. The lowest part of this ridge is a pile of angular bowlders up to a foot in diameter, with the interstices filled with sand.

The till-ridge is prolonged a mile or more to the northeast by a broad elevation of complex structure and topography. The greater portion of its mass seems to be composed of sand, which forms the highest peaks, 65 and 70 feet above lake level. An

area of at least twenty-five acres is studded with mounds and kettles, averaging about one each to the acre. One of these mounds has been excavated, and is shown to be made up of a uniform mixture of two thirds coarse gravel and one third clay. The clay forms a tough cement which holds up the material in a perpendicular face. The mixture might be called a clay conglomerate. A few large boulders occur in this tract. It is continued on the east by an isolated gravel mound rising to 65 feet above lake level.

The system of ridges forms an irregular parallelogram which nearly encloses the basin of High Lake. The northern part of the basin is occupied by a tamarack swamp. The area of open water is about half a square mile, mostly from 10 to 35 feet deep. It is deepest toward the south and west shores. There are no inlets except ditches from a few insignificant marshes, and in summer evaporation equals or exceeds supply. The overflow is by a small ditch to Bear Lake. The basins of the two lakes are really continuous, being only partially separated by the sand and boulder ridge. That their waters were once united is shown by a well-developed beach which borders the ridge and fills the gap between it and the till-spur.

This peculiar grouping of diverse and strongly marked features forms a puzzle difficult of solution. The east-west gravel ridge presents the characters of a subglacial esker, yet its height, steepness of slope, short extent and isolation are unusal. The presence of the great kettle hole piercing its center from top to bottom is not the least remarkable feature and contributes to the general impression of unnaturalness. The north-south ridges are sufficiently esker-like, but the western one is continuous, without notable change in form or direction, with the till ridge. The latter is an esker in form but its material is that of a submarginal moraine. Its northeastward extension presents some of the characters of a pitted sand plain or esker-delta, but it is complicated by the presence of the clay conglomerate and the kame-like sand and gravel knobs. The general indications of the surrounding country are that the Saginaw ice here moved

to the east, southeast and south, but it seems impossible to interpret the local phenomena upon that supposition. If the till ridge is a frontal moraine the direction of ice movement was northward. During the formation of this moraine the ice was traversed by tunnels or cracks which surrounded a block occupying the High Lake basin. These openings formed to some extent the channels of glacial drainage, but the writer finds himself unable to conceive how any considerable quantity of the sand, gravel and boulders in the ridges could have been transported by running water and deposited in such irregular and disconnected heaps. The clearest mental picture he is able to construct is that of a high narrow crack or tunnel, perhaps gradually transformed by the collapse of its roof into an ice-walled canyon open to the sky. Into this crevasse the surface débris slid or was irregularly dumped until it was filled to a height considerably above the tops of the present ridges. The subsequent removal of the walls permitted the pile to spread and assume such form as gravity and the coherence of the material permitted. In form the main gravel ridge is much like the pile of iron ore seen in the yard of a modern blast furnace and perhaps it may be regarded as a dump moraine formed under peculiar conditions. At the position of the large kettle the crack must have divided around an isolated ice-block or island which, although not more than two hundred yards in diameter, persisted through the whole period of filling, the bulk of the material being deposited equally on each side of it. Genetic classification of the system as a whole seems impossible. It might be called an esker-kame-moraine.

About five miles west of High Lake, along the valley of Turkey Creek lies the system of eskers shown in Fig. 2. The valley is here from one fourth to one half a mile wide and bounded by well defined bluffs. The valley floor is occupied for several miles by a peat bog containing a dozen small lakes. About one mile of it is traversed by a series of sand ridges and mounds disposed in characteristic eskerine patterns and contours. The direction of drainage was plainly northward. The main ridge

is 200 to 300 feet wide and fifteen to twenty feet high with a rather flat crest rising in occasional knolls to twenty-five and thirty feet. The northern portion of the series consists of a group of irregular islands and mounds of considerable mass which is perhaps the representative of an esker-delta. No excavations or cuts have been made and the surface shows no material but sand with an occasional small boulder. The arrangement of the ridges and mounds is such as to enclose between them and the bluff the basin of Gordy's Lake of about fifty acres extent and thirty-five feet in depth. High and Gordy's lakes owe their existence and outline to the presence of eskers and they seem worthy to constitute a distinct species of glacial lakes to be known as esker lakes.

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CORRELATION OF THE KINDERHOOK FORMATIONS OF SOUTHWESTERN MISSOURI.

In a recent geological report on Greene county, Missouri,[1] by Professor Edward M. Shepard, the stratigraphy of a portion of the southwestern part of the state surrounding the city of Springfield, has been described in detail. Some of the correlations proposed for the Kinderhook formations, however, are erroneous because of the almost entire disregard of paleontological evidence. The Kinderhook formations in the area are not abundantly fossiliferous, and unless careful search be made for fossils they may be easily overlooked. All the principal formations, however, contain distinctive faunas which furnish the data for a definite correlation of the beds.

The formations described by Shepard that must be included in the Kinderhook, are as follows, beginning with the lowermost, the names being those used in the report:

1. Eureka or black shale	0 to 4 feet
2. King limestone	1 to 15 feet
3. Sac limestone	1 to 18 feet
4. Phelps sandstone	0 to 4 feet
5. Louisiana limestone	0 to 8 feet
6. Hannibal sandstone and shale	10 to 90 feet
7. Chouteau limestone	3 to 30 feet

The most conspicuous of these formations in the region covered by the report are the Sac limestone, the so-called Hannibal sandstone and shale and the so-called Chouteau limestone. In his geological map Shepard has recognized only three divisions in the series which correspond in general with the three formations just named. The Eureka shale and the Phelps sandstone are also formations which are apparently worthy of separate definition, but the King limestone and the so-called Louisiana limestone may prove, upon sufficient investigation, to be nothing but

[1] A Report on Greene county, by Edward M. Shepard, Geol. Survey of Missouri, Vol. XII, pp. 12–245 (December 1898).

lithologic facies of the Sac limestone. The strict correlation of the formations called Louisiana limestone, Hannibal sandstone and shale, and Chouteau limestone with the formations recognized under these names in the central and northeastern portion of the state cannot be sustained, as will be shown in the following pages, and in the present paper the names Northview sandstone and shale and Pierson limestone will be substituted for Hannibal sandstone and shale and Chouteau limestone.

The four lowermost of the formations in the preceding list, were referred by Shepard to the Devonian, but in view of the well defined Kinderhook faunas that are present in the Eureka shale and the Sac limestone, such a correlation cannot be sustained.

Eureka shale.—This formation has been recognized by Shepard in but few localities in the area covered by his map, and is restricted, for the most part, to the southwestern portion of the region where it attains its maximum thickness. Outside of this portion of the area, a few inches of shale have been recognized at several localities lying above the magnesian limestones, which are referred to this formation. Near Frazer's, at the chief locality for the Eureka shale cited by Shepard, the following fossils were collected by the writer:

1. *Lingula* sp. cf. L. *subspatulata* M. & W.
2. *Orbiculoidea* sp. undet.
3. *Chonetes* sp. cf. *C. logani* N. & P. or *C. ornatus* Shum.
4. *Ambocoelia parva* Weller,
5. Phyllocarid crustacean.
6. Fish scales ?

The most common fossils in the fauna are the Lingulas, in this respect simulating the Eureka shale fauna of northern Arkansas which has been described by Williams.[1] *Orbiculoidea* is not recorded from Arkansas by Williams, although there is no reason why the genus should not be present in the Eureka shale of that state. The *Chonetes* found at Frazer's is evidently identical with one of the species of this genus recorded by Williams,

[1] Am. Jour. Sci. (4), Vol. VIII, pp. 139–152.

and is probably identical with one of the common Chouteau species of the genus. *Ambocoelia parva* was first described from the Northview sandstone, and the specimens from the shale seem to be indistinguishable from the types of the species except that they are more or less crushed. No crustaceans are recorded by Williams, but Phyllocarid crustaceans similar to those noticed in the fauna are not of uncommon occurrence in similar shale formations. Fish remains were detected by Williams in the Arkansas beds. No specimens of the *Leiorhynchus subspatula* noticed by Shepard[1] from this locality were detected by the writer.

Notwithstanding the presence of some forms in this fauna at Frazer's which have not yet been recognized in the Eureka shale of Arkansas, and the absence of others which are known to occur there, when we consider the poorly preserved nature of the fossils in all the localities and the stratigraphic relations of the beds containing them, the similarity between the faunas of the two regions is sufficient to establish the correlation, in a general way, of the beds containing them.

In regard to the age of the Eureka shale fauna in Arkansas Williams[2] says:

> The fauna of these fine shales in Arkansas, terminating and following the black shales, is unmistakably much higher than the Genesee black shale of New York. Faunally it is the correlative of the Louisiana or lithographic limestone, and is thus as late as the Kinderhook stage of the Eocarboniferous.

The beds indicated in the quotation are the fine green shales which always follow without any break in the sedimentation, the typical black Eureka shale when the two members are both present. Usually the black shales, in Arkansas, contain almost no fossils save *Lingulus*, but at one locality on War Eagle Creek a fauna from the black shales is noted which does not differ essentially from that in the greener beds.

Recent careful studies among the Kinderhook faunas of the Mississippi valley have given a basis for a more definite

[1] Loc. cit., p. 67. [2] Loc. cit., p. 149.

correlation of the Eureka shale fauna than Williams was able to make.[1] As will be shown, the fauna may be correlated definitely with that of the upper Kinderhook, that portion of the series which lies above the Chonopectus sandstone in the Burlington section.

The specimens referred to *Cyrtina acutirostris* by Williams are probably not representatives of the typical form of this species, but of a variation which may prove to be an undescribed form which is present in the Sac limestone and in the typical Chouteau limestone. *Spirifer marionensis* is a common species in the upper Kinderhook. The species recorded as *S. ? compactus* Meek is certainly *S. peculiaris* Shum., a common and variable species in the upper Kinderhook which possibly runs up into the lower portion of the Burlington limestone. *Athyris hannibalensis* is only a small form of *A. lamellosa*, and the two are not specifically distinct. It is common in the upper Kinderhook of southwestern and southeastern Missouri, but has not been recognized in the Burlington section. The three forms of *Chonetes* recorded by Williams are probably all present in the upper Kinderhook. The species of *Productus* referred to *P. hallanus* Walc. is not that species, but the specimens so identified are identical with a common species in the Sac limestone which has also been recognized in the typical Chouteau of central Missouri and in the upper beds of the Kinderhook in southeastern Missouri. The pedicle valve resembles *P. hallanus*, but the brachial valve does not have the concentric markings of that species. The orthids recorded by William are like those in the upper Kinderhook faunas elsewhere. *Leptaena rhomboidalis* is present in almost every upper Kinderhook fauna but has not been recognized in the Chonopectus fauna, nor in that of the Louisiana limestone. The additional species recorded by Williams afford little evidence as to the age of the fauna.

[1] Many of the Arkansas collections studied by Williams were made by the writer as an assistant to Professor Williams under the auspices of the United States Geological Survey. These collections were also carefully studied by the writer in Professor Williams' laboratory during the winter of 1894–5.

The paleontological evidence, as shown above, points conclusively to the Kinderhook age of the Eureka shale of Arkansas, and not merely may the fauna be correlated with the Kinderhook in general, but with that portion of the Kinderhook which is represented by the Chouteau limestone of central Missouri. The fauna is younger than the Chonopectus fauna of the Burlington section, and is also younger than the fauna of the Louisiana limestone if the generally accepted view as to the stratigraphic position of this formation, at the extreme base of the Kinderhook, be the correct one.

The Eureka shale in Missouri, as described by Shepard, is doubtless a stratigraphic continuation of the Arkansas formation, though the actual time of its deposition may have been a little earlier. The Kinderhook sea, in southwestern Missouri and northern Arkansas, is believed to have been transgressing upon the land to the southward. The Eureka shale facies of sedimentation is believed to have been a transgressing formation associated with the trangression of the sea to the southward, it being the initial sedimentation upon the newly submerged land surface. This formation, therefore, in the region covered by the Greene county report, was probably deposited a little earlier in time than its stratigraphic equivalent in northern Arkansas, as it is followed by the Sac, Northview, and Pierson formations. In northern Arkansas this same stratigraphic unit represents the final stages of the Kinderhook, it being immediately followed by the St. Joe marble whose fauna indicates the Burlington age of the formation. The black Eureka shale in Arkansas, with its associated greenish shale beds and the equivalent Sylamore sandstone, may be considered as the sole representatives of the Kinderhook in that state, the time of their deposition being the final stages of the Kinderhook epoch.

Sac limestone.—The King limestone, described by Shepard, has not been studied by the writer. It is said to be[1] "rarely over a foot or two in thickness except outside and south of the area." A further statement is made in regard to the formation[2]

[1] Loc. cit., p. 71. [2] Loc. cit., p. 72.

to the effect that "to the south . . . . it underlies, directly, the Phelps sandstone, the Sac limestone being absent." This manner of occurrence would seem to indicate that the formation was but a facies of the Sac limestone, it being thin or almost absent where the typical facies of that formation is well developed, becoming thicker and replacing the lithologic facies described as the Sac limestone, to the south. A careful search for fossils should be made in the limestone in order to determine whether or not its fauna is the same as that in the Sac limestone.

The typical facies of the Sac limestone is well exposed in numerous outcrops along the Sac River and its branches in the northern portion of Greene county, the name of the formation being selected by Shepard[1] because of this occurrence. It is a hard, bluish gray, compact limestone with a maximum thickness of eighteen feet, usually deposited in beds of from six to ten inches thick with thin greenish shaley partings between the beds. The rock has been quarried somewhat extensively at several points and shipped to Springfield to be used as curbing. Shepard referred the formation with those beneath it, to the Devonian, considering it to be of Hamilton age. No fossils were secured by him in the formation itself by means of which such a correlation could be established, but in the overlying Phelps sandstone, numerous waterworn fragments of fish-teeth were secured, some of which were identified as *Ptyctodus calceolus*. This genus of fishes is usually considered to be limited to the Devonian, and its presence in beds overlying the Sac limestone was considered to be sufficient evidence to justify the reference of the underlying beds to the Devonian. A study of the invertebrate fauna of the Sac limestone, however, serves to definitely correlate the formation with the lower portion of the Chouteau limestone of central Missouri, and leads to the conclusion that either the waterworn fragments of fish-teeth have been wrongly identified, or that the genus *Ptyctodus* has a higher geological range than has hitherto been supposed.

Although no fossil fauna was secured from this formation

[1] Loc. cit., p. 74.

by Shepard, the Sac limestone is really fossiliferous in most localities where it is exposed, and frequently affords beautifully preserved specimens. One of the best fossil localities in the formation known to the writer, is at an old quarry about eight miles northeast of Springfield, east of the Fair Grove road where it crosses the north branch of the Little Sac. The species collected at this locality will be enumerated, with notes on their occurrence elsewhere.

1. *Platycrinus ollicula* S. A. M.
2. *Platycrinus annosus* S. A. M.
3. *Platycrinus absentivus* S. A. M.

   All three of these species of Platycrinus were originally described from the Chouteau limestone of Pettis county, Missouri.
4. *Dichocrinus* sp. undet. A single specimen of this crinoid has been observed. It is too imperfect for specific identification, but it resembles *D. inornatus* from the upper Kinderhook beds at Le Grand, Iowa.
5. *Schizoblastus roemeri* Shum. This species originally described from the Chouteau limestone at Providence, Missouri, is one of the commonest species in the Sac limestone at the locality under discussion.
6. *Leptaena rhomboidalis* Wilck. This species is entirely absent from the lower Kinderhook beds at Burlington, Iowa, making its first appearance in the upper "Yellow Sandstone," bed No. 5.[1] The species is also absent from the Louisiana limestone fauna of the lower Kinderhook, but is universally present in the upper Kinderhook.
7. *Chonetes logani* N. & P. This little species is particularly characteristic of the oolite bed No. 6[2] of the Burlington section. It is also possible that *C. ornatus* Shum., from the typical Chouteau limestone, is not specifically distinct.
8. *Productus blairi* S. A. M. This species was originally described from the Chouteau limestone of Pettis county, Missouri.
9. *Productella concentrica* H. This species occurs abundantly in the Chouteau limestone of central Missouri, and is also a member of the oolitic limestone (bed No. 6) fauna at Burlington, Iowa.
10. *Schizophoria swallovi* H. The specimens referred to this species are smaller than the normal form of the species in the Burlington limestone. Specimens agreeing in all respects with those from the Sac limestone, are also present in the typical Chouteau limestone.

[1] Iowa Geol. Survey, Vol. X, p. 76. [2] Loc. cit., p. 77.

11. *Rhipidomella burlingtonensis* H. A small form of this species is present in the fauna, which agrees in all respects with specimens from the Chouteau limestone.
12. *Pugnax missouriensis* Shum. The Sac limestone specimens of this species are indistinguishable from specimens of the same species from the Chouteau limestone at Chouteau Springs, Missouri.
13. *Athyris prouti* Swall. This species has not been seen from the Chouteau limestone of central Missouri, but is a common species in the upper portion of the Kinderhook near Sulphur Springs, Missouri.
14. *Athyris* sp. undet. A small species somewhat resembling the Devonian *A. fultonensis* occurs in the Sac limestone fauna, and the same form is present in the Chouteau limestone at Providence, Missouri.
15. *Cleiothyris* sp. undet. Specimens of a small lenticular species resembling *C. hirsuta* are present in the fauna, and the same species occurs in the Chouteau limestone at Providence, Missouri.
16. *Spirifer peculiaris* Shum. This is one of the commonest species of the Sac limestone fauna, as it is also of the Chouteau limestone of central Missouri. The same or a closely allied species occurs in bed No. 5 at Burlington.
17. *Spirifer latior* Swall.? This species was originally described from the Chouteau limestone of Cooper county, Missouri, but no illustrations of it have ever been published. The Sac limestone specimens are identified thus with some doubt, but in any event a species identical with them occurs in the Chouteau limestone of Pettis county.
18. *Spirifer striatiformis* Meek? This identification is only provisional, but specimens of the same species occur in the Chouteau limestone in Pettis county.
19. *Syringothyris missouri* H. & C. This species is only known elsewhere from the Chouteau limestone at Chouteau Springs, Missouri.
20. *Cyrtina* sp. undet. The same species has been recognized from the typical Chouteau limestone.
21. *Dielasma* sp. undet. A rather large, smooth species of this genus is present in the fauna, which is apparently identical with specimens from the Chouteau limestone of Pettis connty.
22. *Capulus* sp. undet. Several forms of this genus are present in the fauna which may belong to several distinct species.
23. Corals and Bryozoa. Several undetermined species of corals and bryozoa of little diagnostic value, occur in the fauna.
24. Fish teeth. Fragments of fish teeth are not uncommon in the fauna.

From the list of fossils just given it will be seen that the fauna of the Sac limestone corresponds closely with that of the typical Chouteau limestone of central Missouri, and more especially with the lower division of the Chouteau limestone as described by Swallow.[1] There is no foundation whatever for correlating it with the Hamilton formation of the Devonian, but several of the species are also present in beds 5 and 6 of the Kinderhook at Burlington, Iowa.

The formation referred by Shepard to the Louisiana limestone, is described as follows by that author:[2]

> The lowest member of the Carboniferous is not so variable in composition and texture as the other two. It frequently, however, possesses such lithologic characters as to make it difficult to distinguish it from the associated Devonian rocks. As only a few obscure fossils have been found in this region, its identification is dependent entirely upon position and lithologic characters.

The Devonian formation referred to in the above quotation is the Sac limestone. The difficulty in separating the so-called Louisiana limestone from the Sac limestone is frequently indicated by Shepard by such statements as the following:

> P. 85: . . . . an outcropping of what seems to be some eight or ten feet of Louisiana, though it may prove to be a somewhat modified form of Sac limestone; p. 76: it is barely possible that this particular rock may be Louisiana, and not the Sac limestone; p. 77: there is frequent difficulty, on account of lithologic characters, in separating it [the Sac limestone] from the Louisiana when the Phelps sandstone is absent; p. 77: it is a noticeable fact that, when the Devonian [the Sac limestone] is present, the Louisiana limestone is usually, though not always, absent.

Among the localities mentioned for the Louisiana limestone, the best exposure where both this formation and the Sac limestone are present, is said to be at the Newton mound,[3] and the description of its stratigraphic position at this locality is as follows: "Immediately underlying the Hannibal shales and overlying the Phelps sandstone, are ten feet of this limestone." The Phelps sandstone at this same locality is described in another

[1] Geol. Surv. Mo., Rep. I and II (1855), p. 102.

[2] Loc. cit., p. 84. [3] Loc. cit., p. 84.

place[1] as follows: "a number of fragments of the typical sandstone with fish teeth were found on the slope. A hurried search did not discover this sandstone uncovered." If this last statement be correct, it is difficult to see how the fact stated in the first of the above quotations can be demonstrated. Another locality mentioned where the Louisiana limestone is said to be "associated with the Devonian" is on the Cochran farm. The so-called Devonian described at this locality is the Sac limestone and "loose fragments" of Phelps sandstone in which "no fish teeth were found." In neither of these localities is it demonstrated that the so-called Louisiana limestone and the Sac limestone are distinct formations separated by the Phelps sandstone. The loose fragments supposed to belong to this sandstone can be of no value in elucidating the stratigraphy. In none of the other localities given for the Louisiana limestone is there any evidence given to show that the formation is distinct from the Sac limestone, and the careful reader of the Greene county report is forced to the conclusion that its author mistook mere lithologic variations of a single stratigraphic unit as two distinct formations. A careful search for fossils, however, should be made in the outcrops of so-called Louisiana limestone, for the purpose of demonstrating its identity with the Sac limestone.

Phelps sandstone.—This formation has been examined by the writer only at its typical locality in the neighborhood of the Phelps mines. It has been recognized by Shepard, however, as a more or less continuous formation throughout the area covered by his report, and is frequently characterized by the waterworn fragments of fish teeth. At the Phelps mines these teeth are somewhat abundant, but are so waterworn that in every specimen observed the original form has been destroyed. Some of these specimens have been identified by Shepard as *Ptyctodus calceolus*, and it was chiefly from the evidence of this identification, with no knowledge of the invertebrate fauna of the Sac limestone, that the Phelps sandstone was referred to the Devonian, such a reference carrying with it, of necessity, all the

[1] Loc. cit., p. 81.

underlying beds down to and including the Eureka shale. This sandstone resembles, lithologically, the Sylamore sandstone of Arkansas; both formations carry fish remains and also numerous black phosphatic nodules.

Northview sandstone and shale. — In the older geological reports these beds have been known as the Vermicular sandstone and shales from the abundance of worm burrows which occur in the sandstones. Shepard[1] has considered these beds to be the equivalent of the Hannibal shales of the Mississippi River section which are supposed to lie beneath the Chouteau limestone, and he has so designated them in his report. These beds in southwestern Missouri, however, are certainly not the equivalent of the typical Hannibal shales, if the relationship of that formation to the remainder of the Kinderhook series be properly understood, and as they possess a characteristic individuality of their own throughout a considerable geographic area, it seems advisable to designate the formation by a special name. The sandstones of the formation are abundantly fossiliferous near Northview, in the western edge of Webster county, and therefore this name is suggested for the formation.

Shepard's investigations have shown that the formation has a thickness ranging from ten to ninety feet. It is typically made up of two members, a lower bluish shale and an upper fine-grained yellowish sandstone. The two members of the formation grade from one into the other with no sharp line of separation, and one member is frequently thickened at the expense of the other, the lower shale member being the most peristent.

The fauna of this sandstone at Northview has been described in detail in another place,[2] and contains the following species.

1. *Zaphrentis* sp. undet. A few fragments of specimens of this genus have been observed.
2. *Scalarituba missouriensis* Weller. This is the name which has been applied to the worm borings which penetrate the sandstone in all directions.

[1] Loc. cit., p. 86.

[2] Kinderhook Faunal Studies. I. Fauna of the Vermicular Sandstone at Northview, Webster county, Missouri. Trans. St. Louis Acad. Sci., Vol. IX, pp. 9–51.

3. *Orthothetes inaequalis* Hall? In the paper cited above, this shell was identified as *O. chemungensis*. It is probably identical with one of the species in the upper Kinderhook beds at Burlington, but may not be the *O. inaequalis*.
4. *Schizophoria swallovi* Hall. The specimens of this species resemble those from the subjacent Sac limestone, and also those from the superjacent Pierson limestone, but are usually larger than the Sac limestone specimens.
5. *Rhipidomella burlingtonensis* Hall. The specimens of this species are not unlike those from the other Kinderhook formations of the region, but are usually larger than the Sac limestone specimens.
6. *Chonetes illinoisensis* Worthen? The specimens so identified should perhaps rather be referred to *C. multicosta* Win., described from the "yellow sandstone" at Burlington, Iowa.
7. *Productella concentrica* Hall. A single individual of this species resembles specimens of the same species from Burlington, Iowa.
8. *Spirifer marionensis* Shum. This is one of the most abundant species in the fauna of the Louisiana limestone at its typical exposures. It is also a common species in the oolite bed at Burlington and occurs in the subjacent "yellow sandstone" at the same place, as well as being more or less common in most of the upper Kinderhook faunas.
9. *Spirifer striatiformis* Meek? This species is probably identical with the one so identified from the Sac limestone.
10. *Syringothyris carteri* Hall. Several specimens from Northview have been referred to this species, although the characteristic syrinx and punctate shell structure of the genus have not been observed.
11. *Ambocoelia parva* Weller. This species has only been observed in this fauna and in the Eureka shale.
12. *Athyris lamellosa* Lev. This species is a common one in the superjacent Pierson limestone, and is also a member of the typical Chouteau limestone fauna.
13. *Cleiothyris* sp. undet. These specimens are possibly identical with those in the Sac limestone.
14. *Dielasma* sp. undet. This shell is perhaps the same as that described by Winchell as *Centronella allei* from the upper "yellow sandstone" at Burlington.
15. *Crenipecten winchelli* Meek? This is a species which was originally described from the Waverly sandstones of Ohio.
16. *Crenipecten laevis* Weller. This species was described from Northview, and is not known elsewhere.

17. *Pernopecten cooperensis* Shum. This is one of the commonest species in the Northview sandstone, and is also one of the most characteristic species of beds 5 and 6 of the Burlington section. It was originally described from the Chouteau limestone of Cooper county, Missouri, and is a common shell in some beds of the Chouteau limestone.
18. *Modimorpha northviewensis* Weller. This species has only been recognized at Northview.
19. *Macroden* sp. undet. This species has not been identified, but the genus is represented in the upper "yellow sandstone" fauna at Burlington by a very common species. The genus is also represented in the typical Chouteau limestone.
20. *Cardiopis radiata* M. and W. This species originally described from the goniatite limestone at Rockford, Indiana, also occurs in the Chouteau limestone in Pettis county, Missouri.
21. *Cardiopsis erectus* Weller. This species was first described from Northview, and has not been recognized elsewhere.
22. *Palaeoneilo* sp. undet. This species was formerly identified with a query as *P. constricta* Con., but it is probably distinct. It is closely allied to *P. microdonta* Win. of the upper "yellow sandstone" at Burlington, but is usually larger.
23. *Palaeoneilo truncata* H. This species, originally described from the Waverly sandstones of Ohio, is represented in the upper "yellow sandstone" at Burlington by *P. barrisi* W. & W. a similar but smaller species. The genus *Palaeoneilo* does not occur in the Chonopectus fauna at Burlington, and has not been recognized in any of the lower Kinderhook faunas.
24. *Schizodus aequalis* Hall. This is a Waverly sandstone species, and has not been recognized elsewhere in the Kinderhook.
25. *Elymella missouriensis* M. & G. This species was originally described from the Chouteau limestone of Pettis county, Missouri.
26. *Promacrus websterensis* Weller. This was described as a new species from Northview.
27. *Promacrus cuneatus* Hall. In the description of the fauna of the Chonopectus sandstone,[1] this species was provisionally included. Since that time, however, through the courtesy of Dr. E. O. Hovey, of the American Museum of Natural History, the type specimen of *P. cuneatus* has been examined by the writer, and it proves to have come from the upper "yellow sandstone," bed No. 5, at Burlington. The genus *Promacrus* is represented by several species in the

[1] Kinderhook Fauna Studies. II. Fauna of the Chonopectus Sandstone at Burlington, Iowa. Trans. St. Louis Acad. Sci., Vol. X, pp. 57–129.

typical Chouteau limestones of central Missouri. It is not known anywhere in the lower Kinderhook beds, and is probably a characteristic form of the upper Kinderhook faunas.

28. *Sanguinolites websterensis* Weller. This species was described as new from Northview, but probably occurs also in the Waverly sandstones of Ohio.
29. *Edmondia* sp. undet. This species was originally identified as *E. burlingtonensis* W. & W., but an examination of the types of that species from the Chonopectus sandstone have led to the conclusion that the two shells are not specifically identical.
30. *Edmondia missouriensis* Weller. This species was described as new from Northview.
31. *Tropidodiscus cyrtolites* Hall. This species, originally described from the goniatite limestone at Rockford, Indiana, is also recorded from the Waverly sandstones of Ohio.
32. *Euphemus?* sp. undet.
33. *Bucania?* sp. undet.
34. *Bellerophon* sp. undet.
35. *Mourlonia northviewensis* Weller. This was described as a new species from Northview.
36. *Pleurotomaria* sp. undet.
37. *Platyschisma missouriensis* Weller. This was described as a new species from Northview.
38. *Straparollus* sp. undet.
39. *Phanerotinus paradoxus* Winch. This species, first described from Burlington, is probably a member of the upper "yellow sandstone" fauna at that locality.
40. *Capulus* sp. undet.
41. *Porcellia rectinoda* Win. (?) The correct horizon of the original types of this species at Burlington is not known. Two other members of the genus, however, occur in the Chonopectus sandstone. The genus is also known to occur higher up in the Burlington limestone.
42. *Loxonema* sp. undet. This species is of the general form of specimens which are not uncommon in the Chouteau limestone in Central Missouri.
43. *Orthoceras indianense* Hall. These specimens, formerly identified as *O. Chemmigense* Swall., are probably identical with a form common in the oolitic limestone (bed No. 6) at Burlington, which may probably be identified with *O. indianense* of the goniatite limestone at Rockford, Indiana.
44. *Triboloceras digonum* M. & W. This species is a common one in some portions of the Chouteau limestone of central Missouri.

45. *Proetus* sp. undet.
46. *Spirophyton* sp. undet. These fucoid markings are abundant everywhere in the sandstone, and with the worm borings are the only fossils which are always recognizable in this formation.

When the description of the Northview fauna was published no differentiation of the faunas of the "yellow sandstone" at Burlington was possible. Since that time, however, a study of the type collections from that locality has shown that two quite distinct yellow sandstone faunas occur.[1] The lower is characterized by *Chonopectus fischeri* N. & P., and the bed containing it, bed No. 2, has been called the Chonopectus sandstone. The upper yellow sandstone is characterized by the presence of *Pernopecten*, *Promacrus*, and *Palaeoneilo*, genera which are wanting from the Chonopectus fauna. These same genera, however, are among the most characteristic forms of the Northview sandstone, and all of them are also present in the fauna of the typical Chouteau limestone of central Missouri. The faunas of the Northview sandstone and of the upper yellow sandstone at Burlington may be considered as analagous, and they may without hesitation be considered as one facies of the upper Kinderhook or Chouteau fauna.

The Northview shales are usually quite barren of fossils, but at a few localities they are abundant. They are mostly brachiopods and corals, but no complete list of species can be given in this place. The collections in Walker Museum contain only a few specimens from this bed near Bolivar in Polk county, the species represented being *Athyris lamellosa*, *Reticularia cooperensis*, and *Rhipidomella burlingtonensis*. These species are all present in the fauna of the typical Chouteau limestone elsewhere.

Pierson limestone.—This is a fine-grained, buff colored, gritty limestone having a maximum thickness, according to Shepard,[2] of thirty feet, being the formation designated by him as the Chouteau limestone. In view of what has already been written in regard to the faunas of the Sac limestone and the Northview sandstone, it will be recognized that the formation is by no

[1] Iowa Geol. Surv., Vol. X, p. 79. [2] Loc. cit., p. 83.

means an exact equivalent of the Chouteau limestone of central Missouri, but represents merely the upper portion of that formation. The formation is well exposed along Pierson Creek near the zinc mines, and since it possesses an individuality of its own as a formation, over a rather extensive area, it may be designated as the Pierson limestone. The formation is frequently non-fossiliferous, but fossils often occur and are usually well preserved. One of the best fossil localities is on the south branch of the Little Sac Creek, about two miles north of Lyman station on the St. Louis and San Francisco railroad. At this locality the following fauna was collected which may be taken as a typical representation of the fauna of the whole formation.

1. *Zaphrentis* sp. undet. A single imperfect specimen of this genus is the only coral of the fauna.
2. *Leptaena rhomboidalis* Wilck. This species is of frequent occurrence in the fauna.
3. *Orthothetes* cf. *O. inflatus* W. & W. A species similar to *O. inflatus*, but much flatter, is rather common in the fauna. The same shell is associated with *O. inflatus* in oolitic bed No. 6 of the Burlington section.
4. *Chonetes* sp. undet. A large species frequently having a width of more than twenty ^{mm} is not uncommon in the fauna. It resembles *C. illinoisensis* Worthern, but is much larger and should perhaps be identified as *C. shumardianus* DeKon.
5. *Chonetes logani* N. & P. ? A species having the general form of *C. Logani* is not uncommon in the fauna, but the preservation is not such as to exhibit the characteristic surface markings of that species.
6. *Productus arcuatus* Hall. This species is particularly abundant in the oolite bed at Burlington, and the Pierson limestone specimens are of the typical form.
7. *Productus burlingtonensis* Hall. Specimens of this species indistinguishable from those in Burlington limestone, occur in the Pierson limestone.
8. *Productus laevicostus* White. This species makes its first appearance in the Chonopectus sandstone of the Burlington section, and ranges up into the base of the Burlington limestone.
9. *Productus punctatus* Martin. Specimens of this species are not uncommon in the Pierson limestone. In the Burlington section it makes its first appearance in bed No. 7, the topmost bed of the Kinderhook at that locality.

10. *Schizophoria swallovi* Hall. Specimens of this species identical with those in the Burlington limestone are present in this fauna.
11. *Rhipidomella burlingtonensis* Hall. Individuals of this species from the Pierson limestone resemble those from the Northview sandstone, and are more nearly like typical representatives of the species from the Burlington limestone than are the Sac limestone specimens.
12. *Camarophoria* sp. undet. This species is of the general form of *C. caput-testudinis* White, the types of which are from the base of the Burlington limestone, and bed No 7 of the Kinderhook at Burlington. The Pierson limestone species, however, differs from *C. caput-testudinis* in being a much smaller and flatter shell.
13. *Rhynchonella cooperensis* Shum. This species was originally described from the Chouteau limestone of Cooper county, Missouri.
14. *Athyris lamellosa* Lev. This is one of the commonest species of the fauna, and specimens from the Pierson limestone are indistinguishable from those in the Burlington limestone.
15. *Spirifer marionensis* Shum. This is the same species that occurs in the Northview sandstone. It is one of the commonest members of the Pierson limestone fauna and also of the oolitic limestone fauna at Burlington.
16. *Spirifer latior* Swall.? The specimens identified as this species are not different from those in the fauna of the Sac limestone.
17. *Spirifer peculiaris* Shum. The Pierson limestone representatives of this species are not unlike those from the Sac limestone.
18. *Spirifer grimesi* Hall. This Burlington limestone species is represented by typical individuals in the Pierson limestone.
19. *Spirifer* sp. undet. This species has the high area of Syringothyris, but lacks the syrinx, and is apparently not punctate.
20. *Reticularia cooperensis* Swall. This species rarely occurs in the fauna. It is a common form in the typical Chouteau limestone and also occurs in the upper "yellow sandstone" at Burlington.
21. *Dielasma* sp. undet. These specimens have the general form and size of those recorded from the Sac limestone, but usually have more conspicuous lines of growth.
22. *Macrodon* sp. undet. A single imperfect specimen of this genus is the only pelecypod recognized in the fauna.
23. *Orthoceras* sp. undet. Fragmentary specimens of a species of Orthoceras are not uncommon in the fauna.

In the Pierson limestone fauna we find a disappearance of the pelecypod element which is so characteristic of the Northview sandstone, and a return of the brachiopods. Some of these

brachiopods are common to the Sac limestone, but there are introduced several species, such as *Spirifer grimesi*, *Productus burlingtonensis*, *Productus punctatus*, and *Athyris lamellosus* (which was also present in the Northview sandstone), which pass upward and connect the fauna with that of the Burlington limestone above.

Conclusions.—A critical examination of the Kinderhook faunas of southwestern Missouri, shows that the entire series of strata in that region referable to this division of the Mississipian series are to be correlated with the upper division of the Kinderhook, or the Chouteau limestone of central Missouri. This Chouteau fauna is not one uniform fauna throughout, but exhibits at least two rather well-defined facies, one brachiopod fancies generally characteristic of the limestones and another pelecypod facies characteristic of the more clastic sediments. In Greene county, Missouri, the brachiopod facies is present in the Sac limestone and the Pierson limestone, while the pelecypod facies is present in the Northview sandstone.

In the Burlington section, beds 5, 6, and 7 are apparently to be correlated with the Greene county formations, and in the faunas of these three beds the same brachiopod and pelecypod facies are exhibited, but in a different order, the pelecypod facies occupying bed 5, and the brachiopod facies beds 6 and 7.

In central Missouri, the region of the typical Chouteau limestone, opportunity has not been offered to study these faunas in situ. Among the material received from that region, however, the same two faunal facies may be recognized, though it is impossible to work out their interrelations without careful field investigation.

These two faunal facies apparently lived contemporaneously throughout the area covered by the upper Kinderhook sea, each one occupying those portions of the region where the local conditions were best adapted to its development, shifting about with local changes in the environment, and each one going on with its developmental changes with the progress of time. The faunas of the Northview sandstone and of bed No. 5 at Burlington,

have so much in common that they may be considered as representatives of a single fauna, yet they may not have been and probably were not strictly contemporaneous. They simply indicate that at some stage during the limited time period in which they both belong, there were present in each of these widely separated regions, conditions suitable for the existence of the same general assemblage of species.

The Chonopectus fauna, which underlies these faunas in the Burlington section, is not represented in southwestern Missouri; neither is the typical Louisiana limestone fauna present in the region.

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PROBLEM OF THE MONTICULIPOROIDEA. II

CRYPTOSTOMATA

Cryptostomata are quite generally classed as Bryozoa, but their reference as such can still be treated as doubtful. They occupy, in fact, a central position in the disputed field of Paleozoic tabulate fossils. They are quite inseparable from Trepostomata which are most often classed as Cœlenterata. To prove them undoubtedly Bryozoa is to prove Trepostomata such also. To fail in that proof permits the latter to be classed as Tabulata, true Cœlenterata, and the Cryptostomata should then be carried with them.

Four similar groups of tabulate corals and bryozoons appear for their first geologic occurrence in the Ordovician (Lower Silurian). The Tabulata, or Alcyonarian corals, are there represented by a few but typical species, the Trepostomata are locally in great numbers, and with them are many Cryptostomata and a few Cyclostomata, the last being true Bryozoa. To the top of the Paleozoic these four groups remain associated, but there the Cryptostomata become extinct. Only in middle Mesozoic the fifth group, comprising the Chilostomata to which most living Bryozoa belong, appears at a time when even the Trepostomata have quite disappeared. The fifth and last group seems to come in suddenly, as did the others. Evidently the record is incomplete as to their origin, and the missing evidence has therefore to be supplied. Some Cryptostomata resemble in all ways the Trepostomata and these the Tabulata; others somewhat nearly simulate the Cyclostomata; and again it has been suggested[1] that they "are nothing more than Paleozoic Chilostomata," differing from these, however, in several ways. The problem centers about the Cryptostomata.

Besides this interest which the problem of phylogenic relationship affords to the paleontologist, the geologist finds, or can

[1] See Eastman, Text-book of Palæontology, p. 278.

find, most of them good zone markers. They are not especially difficult to recognize in the field, their more highly specialized shapes of frond and of cell pattern making them rather easier than Trepostomata in that respect. Their separation into species and arrangement in taxonomic divisions is facilitated by reliable macroscopic external characters as a rule. They afford also a great variety of neat cabinet specimens, and, in short, may be recommended as worthy of close acquaintance.

The student will find a ready knowledge of the Trepostomata a great aid to the understanding of Cryptostomata. In the former group one can select a simple supposed primitive skeletal structure, from which the others can be traced with increasing complexity or differentiation. The simplest Cryptostomata compare with the most complex Trepostomata, and, while serial arrangement of differentiated types can be made, the series appear not to begin within this group but in the Trepostomata. It is, therefore, further convenient to begin with species of this group which most resemble those of the other, avoiding also for the present the taxonomic definitions until after representative fossil species have been studied. The newest taxonomic arrangement[1] may conveniently be referred to, however, and this one divides the sub-order into eight families. They may well be arranged in three divisions or series:

Bifoliate	Cylindrical	Fenestrate
1. Ptilodictyonidæ	4. Arthrostylidæ	6. Fenestellidæ
2. Rhinidictyonidæ	5. Rhabdomesodontidæ	7. Acanthocladiidæ
3. Cystodictyonidæ		8. Phylloporinidæ

The relation of the three groups will be discussed later, but any one might be taken first, since they are coördinate, not successive, but related each to Trepostomata.

Our knowledge of the Cryptostomata may be considered fairly complete, although species and perhaps a family remain to be discovered, while others might be eliminated. This task of completing the knowledge of the several species and genera, their fixed and variable characters, is one worthy of attention

[1] EASTMAN, op. cit., p. 278.

from whoever may be in favorable position to obtain the fossils. For the present the best literature is not to be taken as alike reliable on all. In extreme cases a fortuitous or abnormal character in specimens of a species may have been mistaken as grounds for a new species, and this being then peculiar may be set up as a new genus, and in turn it affects the family. Owing to the more highly specialized structures as compared to Trepostomata, Cryptostomata are, as said, somewhat easier to learn, but they are more complex to study.

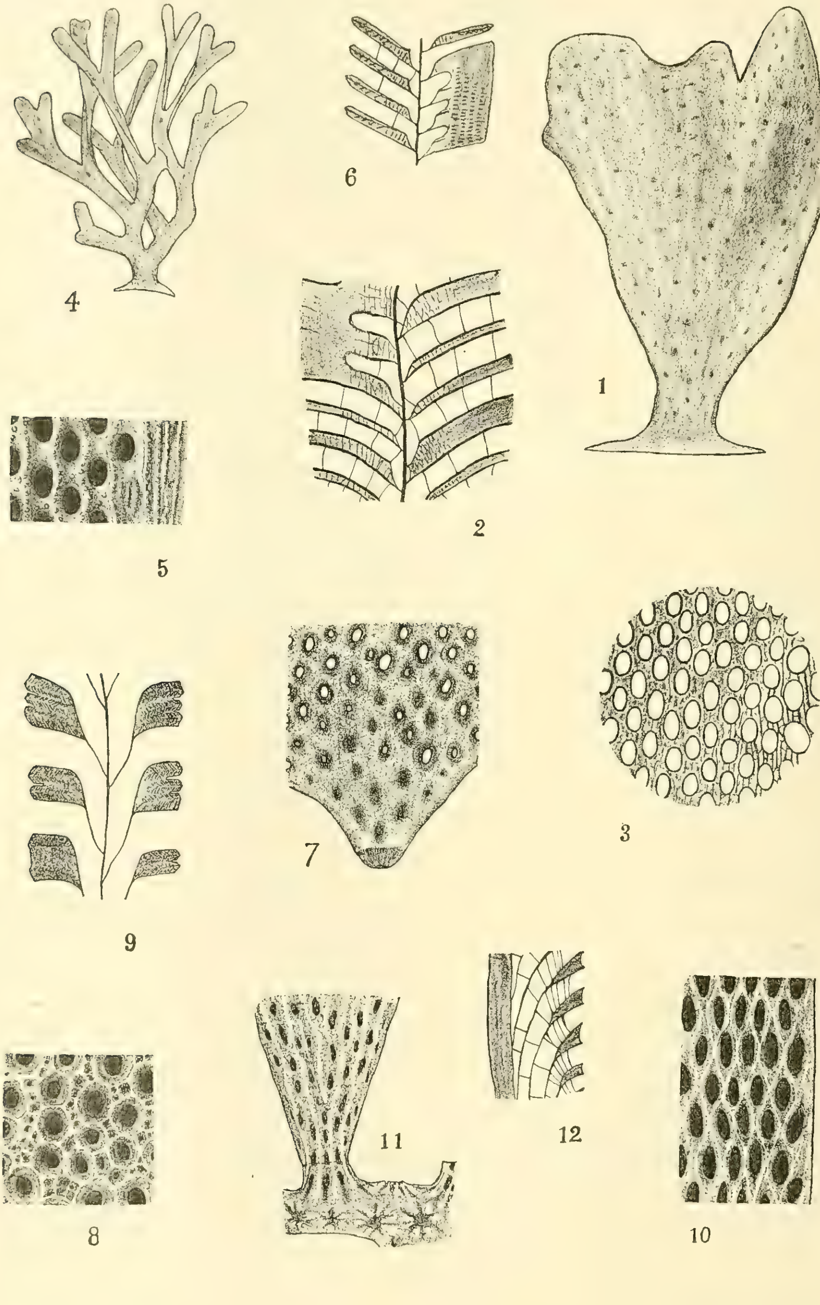
For the present purpose a few common, well-known species suffice. Taking the bifoliate group first:

Pachydictya foliata Ulr. (see Plate B, Figs. 1, 2, 3) is a leaf-shaped zoarium about 50^{mm} wide and 1 to 3^{mm} thick, with autocells 0.3 to 0.4^{mm} in diameter growing from a median plane and opening on either side, "bifoliate." It grows at the margin, the erect frond broadening as it increases in height. The growth is not quite uniform and a lobate, undulate shape prevails. The base or broad stem of the frond is therefore the more mature, thicker part, and there the cell increase ceases first and the margin changes to a solid, sharp, or rounded narrow border. Growing margins may also appear on the face of the frond, and when large, arising near the stem, produce a so-called trifoliate frond. A basal expansion incrusted the ground, and if this was broken off a new one developed from above the broken edge. Any injury destroying part of the frond surface gave rise to a similar growth.

The basal expansion grew perigene, the frond acrogene and so that the zoarial growth and cell increase is normally at the margins only. In the frond the cells arise on either side of a median plane, or so-called mesial plate or lamina, are directed at first vertically, but as younger cells arise between, above them, they turn laterally. Thus an immature or axial and a mature or peripheral region are distinguished. The mesial lamina is built as the extreme wall at the growing edge of the frond.

The cells at the beginning, *i. e.* at the mesial lamina, are thin walled, with mesopores at their angles, but later they are separated

Jour. Geol., Vol. IX, No. 2 Plate B



by mesopores, become oval and thick walled. They grow slowly in the peripheral region, to 1 or 1.5^{mm} in length with slightly increasing size. They have a few thin tabulæ, the first one in or near the axial part, the last one often at the aperture. The mesopores are small, numerous, closely tabulated, either distinct, or the tabulæ of neighboring mesopores overlapping in vesiculose way, or again in maturer stages they fill with granulose schlerenchyma. Mesopore walls are nearly always reduced so that those between mesopores are extant only vertically in zoarial direction, but mesopore corners and junction of mesopore walls to autocell wall are always partly developed. Mesopores are rarely distinct at the surface, and their space appears solid between autocells.

The arrangement of the cells is regular, alternating in vertical rows, and the surface pattern is easily used to distinguish the species. Maculæ or solid spots of filled mesopores and filled cells too, are regularly distributed over the surface and next to these the cells are a little larger sized. No cell increase is seen normally in the peripheral or mature region, not even in the maculæ.

The best specimens only show the peristome or circular wall margin papillose, and the interspaces or mesopore tabulæ granulose, or, when some walls are present, granostriate, as the maculæ and zoarial solid border usually are also. The preserved edge of a growing mesial (or median) lamina, I have not seen, but it was probably papillose. Corresponding to these structures, sections show so-called vertical or median tubuli in the midst of the double autocell wall, similar less distinct structures in the schlerenchyma of filled mesopores, and large ones in the mesial lamina. Warts and so-called tubuli on the interspaces sometimes represent reduced mesopore walls. Further details, dimensions, etc., characterizing the species may be passed over here.

One finds characters in *Pachydictya foliata* Ulr., such only as seen in Trepostomata also: bifoliate zoaria (*e. g.*, *Ceramophylla*), occur among them also: axial and peripheral region, autocells and vesiculose mesopores (*Prosopora*, *Fistulipora*), and maculæ

differ at most in degree of accentuation. The so-called vertical or median tubuli and the mesial tubuli differ most, but are comparable directly to acanthopores. Their numbers and small size here characterizes the species and genus, however, and unites to the Rhinidictyonidæ.

The question arises again as to what interpretation should be made of the zoarium. Apparently the same interpretation is necessary in *Pachydictya foliata* as in Trepostomata. E. O. Ulrich holds that the successive loculi between autocell tabulæ were each a zoœcium, and the autocell was built by successive generations of polypites and as to median and mesial tubuli, that they were a united system of canals. One may prefer the other interpretation for the following reasons. In any case the necessary interpretation is that the skeleton or zoarium was built by a cortex of zooids over its surface, since the mesopores are outside the cells or zoœcia, and must have been been built by super-zoarial secretion; and likewise the median tubuli which end not in the cells but above them. Admitting a cortex to have covered the zoarium, there is no explanation as to why successive generations instead of a single polypite should have built each cell, or how neighboring cells could have had, one four, the other three or five generations to build it. The so-called tubuli can be interpreted as the structural results of surface projections which they are really seen to be. One can explain the mesial lamina of the zoarium in this way, that, as compared to the palmate zoarium of certain Trepostomata, with long narrow axial surface and flat axial region, the bifoliate zoarium has a still more specialized, narrower axial region and the growth or axial edge being thus very narrow, the cortex bent rather than curved over it, the cell walls coinciding with the line of flexure coming to lie nearly in one plane, and to be more or less thickened. The mesial lamina is at the axial growth center, not as a germinal layer but a wall. The cell increase having ceased at full maturity at any part, the margin ceased to extend rapidly and a filled cell or "nonporiferous" margin formed.

Species of *Pachydictya*, *e.g.*, *P. acuta* Hall, might be described

intermediate to *P. foliata* and *Rhinidictya*, but one of this genus may suffice.

Rhinidictya mutabilis Ulr., is bifoliate, with autocells 0.2^{mm} or less in diameter (Plate B, Figs. 4, 5, and 6). It begins apparently as a small thin vertical blade 1 or 2^{mm} wide, with a small basal expansion. It grows in height rapidly, increasing more or less in apical width and branching to the length of 200^{mm} or less. As the zoarium enlarges, its basal expansion widens slowly, the cell apertures filling solid. The base or oldest part of the stalk becomes thick, more or less cylindrical, and solid surfaced. The zoarial branches thicken slowly, having ceased cell increase and built solid narrow margins, the ends either meanwhile growing by cell increase or having finally ceased likewise. Furthur development consists only in thickening of zoarial parts.

Cell increase and greatest zoarial growth takes place only at the apices of the frond and margin of the basal expansion, as in *Pachydictya*. The width of any branch or part depends mainly on the relative growth vigor at the apex in the building of that part. The thickness depends a little on vigor of axial growth but mainly upon age and cell lengthening. At the same time the solid margin extends, so that some width is added to that of the first growth. The initial parts appear to have been small, narrow, dichotomously branching. Some individuals dwarfed or matured at this stage. Others grew long branches, 2 to 8^{mm} wide, dichotomous or palmate digitate. Just below the forks the zoarium is widest, and there a macula appears on medium width branches or a row of maculæ continue down the middle on wider ones, or two to four rows on palmate parts.

The cells alternate in vertical rows. They are somewhat smaller in the initial than in the later zoarial growth stages, but as a rule the widths of the zoarium correspond to numbers of cells and cell rows. Increased number of rows is less by intercalation than by marginal addition at the side of the growing apex, and decrease is by reduction at the margin. Sometimes

a branch widened and narrowed repeatedly, but they usually grew uniformly for a great length. Branches are twisted, heliotropic.

This highly developed zoarium has equally modified cells. As in *Pachydictya* there is a mesial lamina or wall and the thin-walled, prostrate, short, axial parts of cells are in single series on either side, without mesopores, rectangular, or in part drawn out obliquely toward the zoarial margin. The peripheral cell part is sharply defined, both by obliquely outward direction and by a thick complex wall between autocell openings, which are thus a diameter or more apart. This wall comprises the cell walls which appear thin, and between them a mesopore space. In transverse and longitudinal thin sections one may see a tabulated mesopore followed by filled mesopore space, to which the cell walls are amalgamated on either side. What is most novel is a strong dark line or wall dividing the mesopore space. On the surface the mesopore space is elevated, rarely depressed, and the cell aperture rows are in furrows, separated by strong continuous longitudinal papillose ridges, and the apertures in each row by lower short transverse ones. The ridge may be double or again discontinuous, exceptionally. The ridges are the structural cause of the dark line or wall seen within the filled mesopore space. Maculæ have closer parallel ridges, and the zoarial solid margins may appear puncto-striate.

This structural development appears due to the chaining of zooids longitudinally, probably by a canal system which impressed the longitudinal furrows or troughs, causing the mesopore space to be relatively raised. These furrows end at the growing apices of the zoarium, where cells, respectively zooids, were increasing rapidly. As the growing apices became more remote from a given part or ceased, the furrows filled gradually, and a more allsided relation arose between the cells.

No mesopore calycals have been detected and the mesopore space being confluent with the cell calycals, and so far subordinated and fused to the autocell walls, one might conclude that

the corresponding zooids or other structure was reduced to virtually an interautozooidal cortex. Comparison with *Pachydictya*, however, shows the ridges, and corresponding internal structures to be mesopore walls in origin. The so-called tubuli seen in thin section, corresponding to surface papillæ, are then modifications of mesopore walls. The autocell walls proper have none. The so-called mesial tubuli are present. The autocell may have one or two tabulæ in the peripheral region, and at the upper angle, between the axial and peripheral cell, a small hemiseptum may appear.

Similar species to the above described as to frond, compose the genus *Stictoporella*, one of which is peculiar and further instructive:

Stictoporella cribrosa Ulr.[1] is bifoliate with branches about 2^{mm} in width, which bifurcate and anastimose rapidly, growing thus to a large broad frond with numerous oval so-called fenestrules (Plate B, Figs. 7, 8, and 9). The zoarial growth from cell increase is at the branch ends, the margins of the branches, *i. e.*, around the fenestrules very quickly becoming static as to cell increase, although with age the thickening from cell lengthening extends them, constricting or even closing the fenestrules.

Normally the downward end of the initial branch is pointed with striated solid beveled surface, which is supposed to have articulated into the crater-like socket of a striated non-celluliferous basal expansion, forming a movable joint. The wide-spreading zoarial branches coalesce with other zoaria of the same and different species so freely that this joint must have been usually immovable. When part of the zoarium died out, it was regrown by a laminar cell growth, or again fragments of a zoarium grew a new one, in which case a basal expansion unlike the first was developed, or again the fragment became the basal to a lateral fenestrated sporadic growth.

Cell increase is at the growing margin from a mesial plane, as in *Pachydictya*, but the prostrate thin-walled part of the cell is long, overlapping, so that in transverse section the axial

[1] This appears to be the *Clathropora flabellata* Hall!

region is four instead of two cells thick. As the cells turn into the peripheral region the walls thicken and distinct mesopores intercalate. The autocell has a saucer-shaped calycal at the surface and at its center a narrow cell-opening. The small cells or mesopores are either similar, especially in young fronds, or again have the cell opening and even the calycal filled solid, in which case the autocell calycals also become ill-defined, and the surface feature is that of small cell openings and broad rounded interspaces. This condition is the maturer stage. The mesopores are either few and the autocells subquadrangular or polygonal, or again mesopores are very numerous and autocells rounded. Large or small groups of mesopores forming maculæ occur in broader parts of the branches, and the 0.5^{mm} wide border has mesopores only. A constricted, closed fenestrule simulates therefore a macula.

The mesopores frequently differ in size and some of them appear to become autocells, peripheral cell increase thus existing, although necessarily to a limited degree, since the peripheral cells' length is only about equal their diameter.

Thin sections reveal no tabulæ in either autocell or mesopore. The thick walls are dense with a striping parallel to the surface calycal bottoms, *i. e.*, converging upwards to median wall. The mesopore openings are seen to constrict and close while their calycals fill, and then the increments of growth or striping cross them continuously, direct, or arched upward instead of downward across the mesopore space. In this case the amalgamation may be so complete that the appearance is that of one wall between autocell openings. This filling of the mesopore space contrasts with that of *Pachydictya* in that it is by laterally thickened vertical walls instead of by vertically thickened transverse tabulæ. Notably the results are very similar in the end.

In closed mesopore stage the zoarial margins become solid, smooth, or striated, and in the very few zoarial basal stalks seen the autocells also are filled on the surface above the beveled zoarial articulation. Ulrich describes moreover certain closing apercula over cell apertures at the bottoms of calycals, but their

occurrence is sporadic, probably incidental to dying off of the zooids, since these structures never occur within the cell opening as tabulæ, which they should if the zooids survived their formation. This species has no warts upon the walls and no "tubuli."

Ptilodictya (*Escharopora*) *subrecta* Ulr. is a simple bifoliate frond, or if divided the branches do not diverge. The zoarium is sword-shaped or feather-shaped, the point or lower end articulating to a crateriform, striated basal expansion. Specimens vary from 10 to 50^{mm} long, 1 to 10^{mm} wide, and 0.5 to 1.5^{mm} thick. In fossils the basal expansion is separate from the frond, and when living they could have united by a corneous interval or the cortex alone. The frond began evidently very narrow and grew by axial, apical cell increase, the growing end widening more or less and again narrowing somewhat, according to growth vigor. Marginal cell increase near, but below the apex also occurred in some, but the older parts have a solid margin. The cells have rather short prostrate thin-walled axial part and turn more or less sharply into the peripheral direction, the walls here thickening quickly. The cells are arranged, alternating in vertical rows (Plate B, Fig 10). They are at first quadrangular, but before reaching the peripheral region become hexagonal. Here the solid interspace, or wall, thickens, so that oval or subquadrate apertures remain, these being at the bottom of calycals which are confluent in longitudinal rows, or oblique rows in case of the cells that were added marginally. Sinuous, long ridges bound the cell rows (see figure). In later growth thickening, these ridges meet alternatingly at the sinuosities bounding rhombic calycals and finally change to continuous peripheries, the cell apertures becoming meanwhile somewhat larger, subhexagonal, except in the oldest zoarial part or stem where the furrows remain.

Thin sections show the cell walls completely amalgamated, the sinuous longitudinal ridges alone being evident. No tabulæ are seen, except one or two hemisepta. But the exterior of zoaria exceptionally show a few mesopore apertures, these being

in place of the furrows or again at the summit of monticules. The zoarium, if broad, is usually thickest medially, this part then having one, two, or three rows of monticules also. The thicker median part alone appears continued in the stem, which is narrow and thickened to nearly cylindrical form, tapering, ending with a beveled striated articulation area. The articulation area and supposedly the basal expansion grew *pari pasu* with the frond. In old specimens the stalk next to the articulation is solid surfaced, cell apertures having all closed over, except as to the confluent calycals or furrows.

Interpretation of this form from comparison with those described should include in the first place the suggestion that autocells which are evident are separated by completely subordinated mesopores, these being rarely evident, but really always represented in filled condition in the thick amalgamated wall. The confluence of the autocell calycals is explicable as due to the impress of a canal system which was developed strongest in vertical direction during cell increase at the apex; later an all-sided relation between zooids arising, except at the stem, where the basal expansion united. The articulation to the basal expansion shows the zoarium to have been in part non-calcareous. Again, since no pores or even "tubuli" are present, the closing up of all autocell apertures on the stem argues the cells evacuated by the zooids, except as to the calycals. The general manner of development of calycals argues the same.

The hemisepta require special mention. They have been said to have "doubtless served as supports for the movable operculum."[1] The said movable operculum is, however, unknown, and the word "doubtless" is unwarrantable. In fact, the hemisepta occur in some species beneath complete tabulæ, and in those cases they were isolated from the aperture. In *P. subrecta* no tabulæ intervene, and two interpretations may be admitted for sake of argument. The hemisepta occur one at the bottom and one at the top near the termination of the prostrate or axial cell, their position requiring no explanation

[1] Vide Text-Book of Palæontology, by C. R. EASTMAN, Vol. I, p. 279, l. 4.

except reference to some unknown particular cause if considered as accessory opercular processes. I shall add another hypothesis, viz., that they are reduced structures homologous with regular tabulæ similarly situated in other species, *e. g.*, *Pachydictya foliata* Ulr. Their position may be accounted for as related to the sharp turning of the zooid and its cell from axial to peripheral direction, and thus may be taken as evidence that the zooid evacuated the cell as it built. (See text Fig. 2, *A*, p. 169.)

Some smaller closely related species (*Arthropora*) are many-jointed, partly simulating, therefore, the following one. Very probably some cylindrical forms like this one should be considered as to origin as narrow bifoliate, and hence having become rounded.

Arthroclema armatum Ulr. consists of numerous small celluliferous jointed segments which formed a branched zoarium. Numerous primary segments form the main stem, from which lateral branches arise, these being composed of many secondary segments and bearing likewise lateral branches of tertiary segments. These hundreds of segments are each about 3^{mm} long, subcylindrical with generally six or five or four rows of cell apertures, six to ten apertures in a row. The primary segments are 1^{mm} or less in diameter, the others 0.5 and 0.3^{mm} or less.

Each primary segment has a small axial region in which the cells are prostrate, thin-walled, and angular, and a peripheral region which is thickened according to age. The small, rounded cell apertures are separated by solid, longitudinally furrowed interspace and a large prominence behind each aperture. Some of the apertures are closed by constriction near the articulation areas. The ends or articulation surfaces are solid-faced, respectively concave and convex, and the lateral articular socket, when present on a segment, is impressed in the peripheral solid wall. Thin section shows the walls thoroughly amalgamated, the peripheral region merely having striation parallel to the surface.

Secondary and tertiary segments are similar to primary ones partly developed.

A related genus, *Arthrostylus*, has the segments with four sides, one of which is without cell apertures but striated.

Rhombopora lepidendroides Meek. is strictly a cylindrical type. A small, thin basal expansion supports a long, branching, cylindrical stem about 2^{mm} in diameter. There is a central thin-walled axial region in which the polygonal cells may have one tabula, and there is a narrow, thick-walled peripheral region with narrow cell openings without tabulæ. The surface shows oval cell apertures at the center of calycals, these being arranged in transverse, vertical, and oblique rows, their margins being more or less in contact. The elevated interspace has rows of small warts, which divide the zoarial surface somewhat into rhombs, including each a calycal. Usually a second larger set of warts or acanthopores are situated at the junction of the rows. The internal wall structure corresponds, *i. e.*, the thin, dense walls of the axial region change quickly to thick in the peripheral region, with striation parallel to the calycal, interspace, and wart surfaces.

There is no distinct evidence of mesopores, but a simulation of maculæ and other characters in common with the forms of Trepostomata, genera *Batostomella*, *Eridotrypa Batostoma*, which they approach more closely than to other than cylindrical Cryptostomata, would indicate that the interspaces are mesopores rather than thickened autocell walls alone.

Phylloporina corticosa Ulr. belongs to the reticulate series, and has a reticulate frond and solid basal expansion (Plate B, Figs. 11 and 12). The frond is composed of so-called branches 0.5 to 1 or 2^{mm} wide, which anastimose laterally at somewhat regular intervals, producing elongate fenestrules. Each branch has cells on the obverse side, but none on the solid, smooth or striated reverse side. Thin sections show that the cells arise mesially, have a long, thin-walled, tabulated prostrate portion, then become more closely tabulated as they turn slowly into the peripheral

region. The axial cells overlap so as to be three or more deep in transverse section. The peripheral region is characterized by filled interspaces or mesopores which more or less completely separate the cells, the cell margins rising a little above the interspace at the surface. Zoarial growth as to cell increase took place only axially, *i. e.*, at the branch ends. The peripheral growth comprised thickening of the branches with cell lengthening on the obverse side and with about equally as thick, solid or rarely vesiculose increment on the reverse side, thus proving the branch to have been surrounded by a secreting cortex. Young branches usually have on the obverse a median keel, the edge of a wall or walls extending from the mesial line, and this E. O. Ulrich compares to the longitudinal ridges dividing cell rows in *Rhinidictya*. It bears a few acanthopores. An obtuse keel on the reverse produces no internal wall distinction. With age the keels disappear from the then rounded or flattened obverse and reverse sides, and the fenestrules constrict, even closing some of them. Branches are 1 to 2^{mm} thick.

The cell apertures are arranged in one or two rows on each side of the median keel, or a few more at inosculations.

The basal expansion is the key to the better understanding of this zoarium. To the description of it as "an expanded base," the following is added from specimens at hand: Basal expansion thin, incrusting, about 2 or 3^{cm} in diameter, the marginal or younger part bearing stellate monticules like those of *Stellipora* (*Constellaria*), *i. e.*, a central depressed macula with six to twelve rays, between which are as many sloping ridges of autocells. These monticules or stars are about 3^{mm} in diameter. The rest of the expansion is crowded with young stars between larger older ones of various sizes. It appears that the stars increase in size by addition of a few ridges, all of the ridges elevating rapidly at their proximate ends. When about 1^{mm} high they begin to anastimose, and they continue to grow and elongate upward, anastimosing and branching, whence arises the reticulate funnel-shaped frond, with cell apertures turned to the outside and a solid, striate surface on the inner side; the obverse side of the

branches arising from the celluliferous ridges of the monticule, the reverse solid surface continuing from the central macula, which has become solid or coarsely vesiculose, succeeding distinct mesopores, and forms the bottom of the funnel. The median keel of the obverse side is, again, the continuation of that of the ridge in the monticule stage, the same as appears in the ridges of stars on *Stellipora*. The arrangement of the cells on the branches originated likewise in that of the stars. The basal expansion bears one largest frond, two to five smaller ones, and several monticules of various degrees. The internal structure of the basal is more similar to *Stellipora* than to that of the frond or reticulate part of *Phylloporina*.

The grown funnels must have crowded each other, and in fact fossils evince irregular shape in their later stages. Some evidently met accident, since specimens occur in which a new growth arises from the broken edge of an older piece and in a new direction. Also, a secondary basal lamina may develop from the poriferous side of a fragment, bearing new somewhat regular stars or monticules. A fragment may convert itself into a single large monticule or new basal, and other variations occur.

The long cells with many tabulæ in *Phylloporina* are remarkably like those of Trepostomata. The basal expansion like a *Stellipora* and the development of the reticulate funnels from monticules suggests relationship with Trepostomata and not with bifoliate Cryptostomata. There is not then any relation between the *Stictoporella cribrosa* type of anastimosing branches and the similarly anastimosing parts of *Phylloporina*, which might better be called bars than branches to distinguish them.

Other truly reticulate forms probably derived from *Phylloporina* as E. O. Ulrich suggests.[1]

Septopora biserialis (Swal.) has branches or bars 0.8 to 0.3^{mm} wide, dividing laterally, and united at intervals by transverse processes called dissepiments, rather than anastimosing,

[1] EASTMAN, op. cit., p. 281.

the whole forming a fenestrated frond with primary branches or bars arising from an irregular basal attachment, and from these a little narrower, parallel to slightly radiating ones. The fenestrules are rather wider than the bars; ten bars occur in 1^{cm}. They have celluliferous obverse side and solid reverse, the latter on the outer or under side of the zoarium and forming the basal expansion and sometimes rootlike anchors at intervals above it. From the base a more or less funnel-shaped stalk supports the large frond on one side.

The cell apertures are about 0.13^{mm} in diameter and on the bars are arranged in two rows, separated by a thin median ridge which bears more or less prominent small warts or acanthopores. The dissepiments have distributed cell apertures only.

The internal structure seen by thin sections consists of short prostrate thin-walled axial cells arising mesially, turning sharply into the peripheral region where they become surrounded by interstitial solid deposit. Thus the cells have the appearance of being thin walled "enclosed in a calcareous crust," since the mesopore spaces on the obverse and the equally thick solid deposit on the reverse, surround the cells. There is a median wall or structure corresponding to the median ridge. The reverse is longitudinally striated at first, later nearly smooth, and its internal structure corresponds thereto. Further, it has been claimed that the solid deposit on the obverse and reverse had small vertical pores ending in minute warts at the surface, but that the dim structures so interpreted were open tubes may well be doubted. Another feature, the so-called dimorphic pores (cells), arise in the solid deposit of the reverse and obverse, are somewhat smaller than the regular cells but at the surface end with slightly elevated peristome like these. They are not to be wondered at, since they arise in what is homologous to mesopore space in, for example *Stellipora* or *Stictoporella*, and may be taken as evidence that peripheral cell increase had not wholly disappeared. The cells have no tabulæ, but sometimes a hemiseptum.

The dissepiments in this zoarium are comparable both to

drawn out inosculations from which they may have arisen and to side branches to which they are tending. The relation of obverse and reverse of the frond is a little strange, since they are reversed as compared to *Phylloporina*, the basal expansion also being unlike in that genus; differences which I cannot explain, but yet are of small import since closely related genera as *Fenestella* and *Semicosmium* differ in just that way. I feel not assured that the primary basal expansion is known except in *Phyllopornia corticosa* Ulr.

DISCUSSION OF CRYPTOSTOMATA.

These described species may suffice to represent the Cryptostomata. The species of *Pachydictya* and *Rhinidictya* are of the Rhinidictyonidæ; *Stictoporella* and *Ptilodictya* of the Ptilodictyonidæ; nothing especially different is seen in the Cystodictyonidæ except sometimes a lunarium like that in the Trepostomata; *Rhombopora* is of the Rhabdomesodontidæ; *Arthroclema* of Arthrostylidæ; *Phylloporina* of Phylloporinidæ; *Septopora* of Acanthocladiidæ; and the Fenestellidæ are merely distinguished from the latter by having dissepiments without cell apertures on them. In these all, and those which they are taken to represent, the growth is acrogene and cell increase is almost all axial. Axial and peripheral regions are sharply defined, cells short, and mesopores filled more or less solid.

The Cryptostomata differ in degree of specialization of structures rather than in kind from the Trepostomata. In fact, they are arbitrarily divided in all respects. The defined axial and peripheral regions of zoarium appearing to arise in Trepostomata are merely as strongly to stronger developed in Cryptostomata. So also are the long, tabulated cells changing to shorter, with or without tabulæ and so-called hemiphrams or hemisepta. Peripheral cell increase is only reduced to nearer the minimum. The mesopores begun apparently as young cells in Trepostomata and developing to subordinate special structures or vesiculose to solid interstitial filling, are vesiculose to solid in Cryptostomata. Monticules ranging to the extreme

from called maculæ in the former are represented by maculæ in the latter. Indeed, sharply defined peripheral region, short cells, reduction of tabulæ, hemiphrams, filled vesiculose or solid mesopores, and solid maculæ, so-called acanthopores, and mesial lamina, lunarium, etc., are found in highly specialized Trepostomata of the Fistuliporoid type.

There is no character in Cryptostomata that distinguishes them all from Trepostomata. The former comprises essentially certain families of highly modified zoaria related to Fistuliporidæ of Trepostomata. They are not a single branch from these, but three or more, as seen when examples like *Pachydictya*, *Rhombopora*, and *Phylloporina* are compared. The genera named are the Cryptostomata, which are scarcely separable, if at all, from Trepostomata, but are not related one to the other as closely as to Trepostomata. They compare back to *Cramophylla*, *Eridotrypa* and *Stellipora* respectively, which belong to three different recognized families of *Trepostomata*. They belong to more than distinct families, to three divisions of Cryptostomata, the frondiferous, cylindrical, and reticulate respectively. The highest differentiated Cryptostomata, also, for example, *Ptilodictya* and *Fenestella* unite to not the same Trepostomata-like Cryptostomata. The question should be rather on the propriety of dividing the Monticuliporoidea at all than on the probability of Cryptostomata and Trepostomata belonging to different phyla.

As to the interpretation of the zoarium of Cryptostomata, the entire skeleton, excepting the under side of the basal expansion, was covered by some kind of cortex uniting the zooids, as proved by deposits of superimposed laminæ in intercellular spaces, on solid margins, and on the reverse surfaces. The zooids built and evacuated the cells, resting more upon than in them at maturity, as proved by tabulæ close to the aperture, by closed-up autocells, as in the stem of bifoliate zoaria, and by the building of skeleton exclusively at its outer surface. Subordinated zooids, in some degree of development, were always present, since mesopore spaces, distinct or filled, are always present in the peripheral region. Solid maculæ, solid zoarial

margins, and solid obverse of reticulate ones are mesopore areas being seen sometimes as such (*e. g.*, *Stictoporella*, *Phylloporina pars*, *Semicosmium*), and are probably all really maculæ covered by subordinated zooids, or at least a cortex. Longitudinal median ridges and walls arise variously. Again, in jointed forms (*Ptilodictya*, *Arthropora*, *et al.*) part of the skeleton was not calcareous. These show reduction from the entirely calcified zoarium, and also the filling up of mesopores and some autocells might be readily interpreted as due to leveling down of division walls between zooids: a process of reducing thin-walled cell mass to a solid axis within a living cortex.

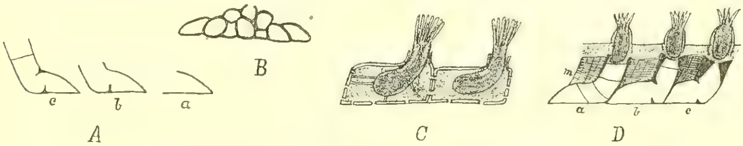
A quite different interpretation from that just given is expressed in the current definitions of Cryptostomata. Vine[1] defined them, "Zoœcia tubular, subtubular, in section slightly angular. Orifice of cell surrounded by vestibule, concealed." He does not speak of tabulæ, mesopores, acanthopores, etc., and only later knowledge, especially by E. O. Ulrich, has changed the definition, adding to *vestibule*, "which may be intersected by straight diaphrams or hemisepta owing to superimposition of layers of polypides," "surrounded by vesicular tissue or solid calcareous deposit." Vine, having in mind such as *Septopora* and *Ptilodictya* without tabulæ, seems to consider the cell as a permanently occupied zoœcium; Ulrich includes the richly tabulated *Pachydictya*, *Phylloporina*, etc., and speaks therefore of superimposition of polypides or zoœcia. More direct interpretation would indicate each cell to have been gradually built and evacuated by one zooid, as argued in the preceding pages. For corresponding explanation of hemisepta see text, p. 161.

The separation of Cryptostomata from Trepostomata is scarcely tenable, and they may be discussed together. The zoarium of Cryptostomata is merely the more differentiated, the simplest Trepostomata and the typical Cryptostomata being extremes in the same line. This developmental series might well be compared to the reduction of thin-celled Tabulate corals

[1] Brit. Assn. Rep., 1883, p. 184.

to a solid axis,[1] details of which may be omitted here, since there is no character in Cryptostomata as also in Trepostomata negative to supposed relation of Monticuliporoidea to Tabulate corals as already discussed, unless, as said, their relation to Bryozoa can be proved.

In comparing to Cylostomata to which Cryptostomata have been sometimes referred, *Stomatapora* and *Berenicea* come first into consideration. Vine referred them to Cryptostomata in



AFFINITIES OF MONTICULIPOROIDEA.

FIG. 2. Diagrams showing: *A.* Interpreted origin of inferior and superior hemiseptum. *a*, axial cell stage; *b*, turning stage; *c*, peripheral stage, hemisepta remaining at points where the relation of zooid and its cell changed most. *B. Proboscina minnesotensis* Ulr., transverse section. × 40. *C.* Relation of zooids of Bryozoa to their cells, for comparison with *D*, the interpreted relation in Cryptostomata. *a*, tabulated cell as in *Pachydictya; b*, cell with hemisepta as in *Ptilodictya; c*, cell closed by wall-thickening as in same.

fact. These genera comprise essentially the Paleozoic Cyclostomata, and range from Ordovician to Recent times. *Stomatopora* (*e. g.*, *S. inflata* H.) forms branching single series of club-shaped prostrate free cells, each arising from under the anterior, larger end of the preceding one, and having a small circular aperture on the anterior upper side. Its walls are said to be minutely porous if well preserved. *Stomatopora* is not comparable to any of the Monticuliporoidea, but is a key to species called *Proboscina* or *Berenicea.*

Proboscina minnesotensis (Ulr.) forms two, three, or more series of prostrate cells, each arising from under the anterior of the preceding cell of its series. The anterior end is drawn out upwards, making a vestibule, as it is called, bearing the round aperture. The cells appear superficially as immersed in a band of stereom, but thin sections show only compacted, thin-walled

[1] *Pachypora, Corallium*, etc., see Neues Jarb., Beilb. X, p. 306–312.

cells (text Fig. 2, *B*), the alternating apertural ends being rounded, the other cells at that point being appressed, angular. The walls are poorly preserved as compared to fossil brachiopods and corals upon which they have grown, but very probably the basal side of the cell only was porous. Sometimes the bands or branches become very wide, thus approaching nearly *Berenicea* proper, in which perigene growth, like that of incrusting monticuliporoids is simulated. Since *Stomatopora* and *Berenicea* include also Recent species, their position as Bryozoa is established. The serial relation of other Cyclostomata and the rather similar zoaria of Chilostomata are further well shown in handbooks, and will not be discussed here.

In comparing *Berenicea*, including *Proboscina*, one at once notes that there are no tabulæ, no monticules or maculæ, no mesopores, no thick walled region, that the apertural vestibules are free and cell walls perforate. Monticuliporoid cells have imperforate walls. Further, all monomorphic monticuliporoids are again different, having without exception apertures of cells crowded together. Dimorphic forms with tabulæ are also to be excluded, while dimorphic, short celled, non-tabulate forms may be admitted to closer comparison. In fact, such as *Protocrasina* (Eastman, *op. cit.*, p. 262, Fig. 417) appears to be, might be bryozoon or monticuliporoid as to its outward aspect, the nature of its walls as poriferous, thin, or dense, thick, being the determining difference. But the comparison requires the Cyclostomata to be viewed as derived from highest specialized Monticuliporoidea, the dense autocell walls of these to be explained as having become porous in *Berenicea*, *et. al.*, and the thick, solid mesopore spaces reduced to a minimum, and thus at once a weak chain of hypotheses or an arbitrary definition is required to unite the nearest Bryozoon, *Berenicea*, to Monticuliporoidea.

Other Cyclostomata differing from *Berenicea* in changing the prostrate growth into bifoliate, acrogene, or massive form, and the cell apertures and vestibules from free to more or less in contact as in *Osculipora*, *Aspendisia*, etc. (Eastman, *op. cit.*, pp. 264–265), resemble thereby such monticuliporoids as *Stellipora*,

Septopora, etc., but only superficially. The Cerioporidæ (*op. cit.*, p. 266) most resembling Trepostomata have porous walls and are in the second place not well determined. If viewed as derived from Trepostomata the walls being assumed as having become porous — an admissible hypothesis — this hypothesis requires a reverse view of the evolution of Cyclostomata from the first one, *i. e.*, that the long tabulated cell, not the short open one, is the more primitive in Bryozoa.

The same differences disunite Chilostomata as Cyclostomata from the Monticuliporoidea, where also their outward appearance is similar, as for example *Retopora* (*op. cit.*, p. 289) and *Septopora*.

The greatest importance rests on the interpretation of the zooid's position with reference to the cell. In Bryozoa the zöoid inhabits closely the cell. In order to refer Monticuliporoidea to Bryozoa it appears essential that the zooid be considered as occupying the cell and Vine has so interpreted in his definition of Cryptostomata, as said. In cells without tabulæ of some species the interpretation might appear logical (*e. g.*, *Ptilodictya*, except on the stem) but other species have tabulæ (*e. g.*, *Phylloporina*), whence the interpretation of superimposition of zoœcia and of zooids. This interpretation then unfortunately assumes that which most requires proof. If there is anything clear in Monticuliporoidea it is that the cell is the unit structurally in every zoarium, that loculi between successive tabulæ can not be coördinated as such units because of inconstancy alone. They vary in length and breadth ratio from 1×10 to 10×1 and more, in the same zoarium. The interpretation of loculi as zoœcia precludes all uniformity of size and shape of zoœcium. In fact, the loculi are not described as structurally units in any species — but the cell. In the definition of orders only the successive loculi have been called zoœcia, an interpretation that is simply not supported by any evidence from the zoarial structure.

Interpreting the cell, not its loculi, as the zoœcium a great difference is at once evident between Bryozoa (text Fig. 2, *C*) and Cryptostomasa (Fig. 2, *D*) and Monticuliporoidea in general in the position of the zooid — a matter of greater importance

than tabulæ, hemisepta, acanthopores, communication pores, etc. Moreover, tabulæ characterize the Monticuliporoidea and true pores the Bryozoa. One cannot assert that no bryozoons have tabulæ but they probably do not. The superimposition of cells frequently occurs in monticuliporoids and in bryozoons, but forms a recognizably distinct structure from that of the tabulated cell proper. One finds, again, many descriptions of pores in Monticuliporoidea but none recognizably like those in Bryozoa, which run direct, transverse, through the cell wall as communication pores. The supposed pores parallel the cell walls and do not end in the cell, and if they were demonstrably pores, their difference would rather serve to separate the group from true Bryozoa. They are not pores in most cases. In case of the reticulate cryptostomata one might not wish to deny that pores could exist, but yet their existence is notably only in the mesopore space or outside the autocell wall, and might be interpreted like the minute porousness of some corals (Tubipora) due to living cells remaining in the stereom, rather than as canals.

SUMMARY

Briefly reviewed the Monticuliporoid zoarium consists, in the first instance of monomorphic tabulated cells, differing from the extinct *Chaetetes* corals in the cell increase being less often by fission than budding. In the second instance, the young closely tabulated cells develop with a retarded or mesopore stage preceding full size growth. In the third, many cells appear to be permanently mesopores, autocells however arising from mesopores. Some autocells displace several mesopores in their rapid growth expansion and the mesopores are either distinct or their bounding walls imperfect and tabulæ vesiculose. This development and its minor features is paralleled in living and fossil Alcyonarian Tabulate compound celled corals. In the fourth instance the cells are shortened, and the mesopores or interstitial space filled solid either by superimposed tabulæ or by thickened bounding walls : cells with few or no tabulæ or filled : Cryptostomata.

There is an accompanying differentiation from uniformity in the first instance to marked axial and peripheral region of the cell in the fourth and other characters incidental therewith. But all things considered the monticules and their special form maculæ, are all that separate the Monticuliporoidea from other Tabulate (Alcyonarin) corals, but apparently not from certain living Alcyonaria, which have possibly descended from them.

As to Bryozoa, two hypothetical comparisons with Monticuliporoidea are to be considered. First, the Cerioporidæ including *Heteropora*, may be Bryozoa derived from Monticuliporoidea in the first instance just mentioned, the solid wall having become porous with transverse canals. Secondly, Berenicea and other Bryozoons with more or less free vestibules might have derived from the fourth instance, being then a fifth stage or instance, the mesopore solid filling having reduced to nothing and imperforate cells walls having become perforate.

The Monticuliporoidea are difficult to separate from corals in two concordant instances. In two instances in which their structures nearest approach the Bryozoa, they separate easily or rather are difficult to unite with them, and of these instances the one probably negatives the other.

EXPLANATION OF PLATE B.

FIG. 1. Pachydictya foliata, frond natural size.

FIG. 2. Pachydictya foliata, longitudinal section. × 10.

FIG. 3. Pachydictya foliata, tangential section. × 10, showing cell pattern.

FIG. 4. Rhinidictya mutabilis, frond of an undersized individual.

FIG. 5. Rhinidictya mutabilis, part of surface. × 20, after Ulrich.

FIG. 6. Rhinidictya mutabilis, longitudinal section. × 10.

FIG. 7. Stictoporella cribrosa, lower part of frond with articulation.

FIG. 8. Stictoporella cribrosa, surface. × 20.

FIG. 9. Stictoporella cribrosa, longitudinal section. × 20.

FIG. 10. Ptilodictya subrecta, surface. × 20 showing zoarial margin.

FIG. 11. Phylloporina corticosa, part of basal expansion and one frond. × 2.

FIG. 12. Phylloporina corticosa, longitudinal section. × 20.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.,
November 5, 1900.

Studies for Students

THE STRUCTURE OF METEORITES. II.

(Continued from page 66)

CHONDRITIC STRUCTURE

This characterizes the great majority of stony meteorites, and being peculiar to meteorites will be described in detail. Of the 314 stone meteorites listed by Wülfing in his recent classification, 288 are more or less largely composed of chondri. Some meteorites are composed of chondri almost exclusively (Borkut) while others contain them imbedded in a groundmass. The latter may be tuffaceous, glassy or crystalline. The term chondrus, plural chondri, is from the Greek χόνδρος, a grain, the term being applied in reference to the size and shape of the body. Some writers prefer the diminutive form of the word, viz.: chondrules. In size chondri may vary from that of a walnut to a dust-like minuteness. The larger number are about the size of millet seeds. The form of chondri is generally spheroidal, but varies from essentially spherical to mere irregular fragments. Some chondri are flattened or oval and others show apparent deformation subsequent to their origin. In the latter, depressions or projections occur which often look as if a hard chondrus had pressed against another soft one during the process of formation. The deformed chondri pass by every gradation into those which appear to be rock fragments with rounded angles. The surface of the chondrus is rarely smooth, being usually rough or knobbed. From many friable meteorites individual chondri can easily be isolated, but if the meteorite is at all coherent the chondri break with the rest of the mass. The color of chondri is usually white or gray, but some are brown to black. As they are often of the same ingredients as the groundmass in which they are imbedded

they may differ little in color from it. On this account and on account of an ill-defined contour they may be overlooked and a crystal may be considered porphyritic, which is really part of a chondrus. Usually, however, the chondri are plainly marked

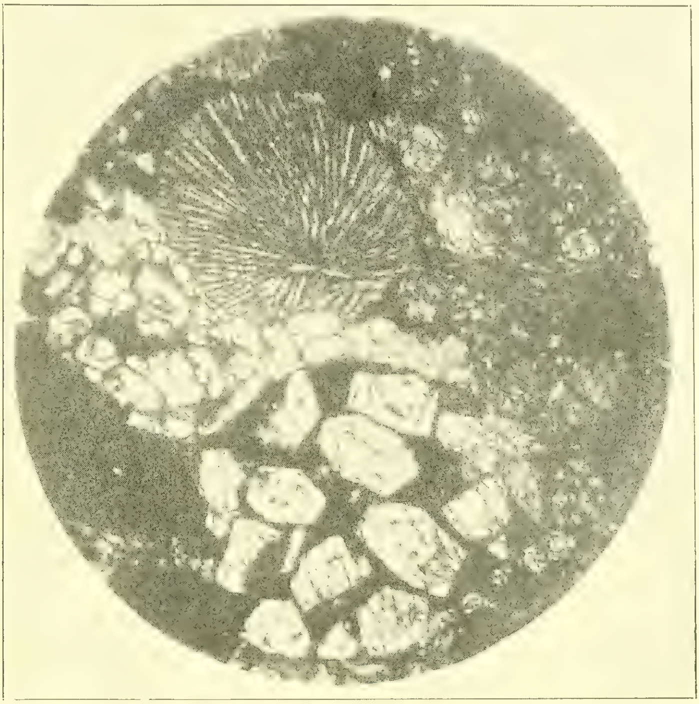


FIG. 7.—Section of the Homestead meteorite, showing a typical eccentrically-radiating bronzite chondrus (above) and a porphyritic chrysolite chondrus (below). A granular chrysolite chondrus also appears at the left. × 65. After Tschermak.[1]

on a polished section by differences in color and contour. In structure chondri may themselves be granular, porphyritic, coarsely or finely fibrous. They may consist of a single crystal individual, in which case they are said to be monosomatic, or of several individuals, when they are said to be polysomatic.

[1] Die mikroskopische Beschaffenheit der Meteoriten. Tafel VII, Fig. 4. Figs. 2, 3, 4 and 5 of Article I should also be credited to Tschermak, Lehrbuch der Mineralogie, 4th edition, p. 585.

True monosomatic chondri are confined almost exclusively to the mineral chrysolite. They can be known by their simultaneous extinction in polarized light. Polysomatic chondri may be made up of different minerals as well as different individuals and may show more than one kind of structure, *i. e.*, a chondrus may be granular in one portion and fibrous in another. The following minerals are noted by Tschermak as forming chondri, their relative abundance being in the order named : Chrysolite, bronzite augite, plagioclase, glass, and nickel-iron. This order, it is to be noted, is also that of the fusibility of the minerals, the most infusible and hence the earliest cooling mineral forming the most chondri. Chrysolite chondri usually contain large quantities of glass of a dark brown color. This may be arranged (*a*) in the form of alternating layers, in which case a marked rod-like or lamelliform appearance is produced, or (*b*) may form a base in which the mineral is developed porphyritically, or (*c*) may occur in the center of a crystal, or (*d*) may form a network. Polysomatic chondri of the latter sort are especially liable to be mistaken for those of bronzite since they simulate the fibrous appearance of the latter. Occasionally the crystallization may have proceeded only far enough to produce skeletal or branching growths of the mineral among the glass. Both monosomatic and polysomatic chrysolite chondri may have the arrangement of a well-marked rim about a spherical interior. This rim may, in the polysomatic chondri, be composed of many individuals. Such a rim is often dark from a content of iron and troilite. Chromite, either in minute grains or in dust-like aggregations, also forms a common inclusion usually near the surface of the chondrus. The quantity of opaque inclusions may be so great as to give the chondrus a black color. Such chondri associated with those of light color are to be found in the stones of Knyahinya, Mezo-Madaras and others. The constituent minerals of such chondri are chiefly chrysolite and bronzite. Bronzite chondri are usually of a finely fibrous character. The fibers instead of radiating from a center as do those of spherulites usually radiate from an eccentric point. This eccentric arrangement constitutes one of

the most marked features of the chondri and separates them sharply from any formation seen in terrestrial rocks. The bronzite chondri have less glass than those of chrysolite. Monosomatic chondri of bronzite have never been observed, the large

FIG. 8.—Section of the Dhurmsala meteorite, showing a large, somewhat porphyritic chondrus enclosing a smaller monosomatic one. Both are composed of chrysolite. × 8. After Tschermak.[1]

crystal individuals showing, as a rule, no tendency to a spherical form. Besides bronzite chondri having an eccentric arrangement of fibers there occur those which are confusedly fibrous, and these may pass into those which have a netted appearace from crossing fibers. Such chondri, cut at right angles to the fibers, show the fibers to have a concentric arrangement. The

[1] Op. cit. Tafel VIII, Fig. 1.

chondri already mentioned, which are granular in part and in part fibrous, are usually made up of the two minerals chrysolite and bronzite. These minerals may be present in about equal quantity or either may be in excess. Usually the bronzite together with glass appears to occupy the intervening spaces between the chrysolite grains, indicating that it is of later formation. Augite chondri are not common but occasionally occur. They often show a structure which indicates repeated twinning. The mineral may appear also in the form of grains, usually of a green color. These grains can be distinguished from chrysolite by their behavior in polarized light. Chondri containing plagioclase in any large quantity are also rare but have been observed by Tschermak in the stone of Dhurmsala. The plagioclase alternates in bands with chrysolite and is in excess. Chondri also occur which are composed almost exclusively of glass, the only indication of the presence of other minerals being in the presence of forked microlites which may be referred to bronzite. Occasionally these microlites are of a pronounced star-like form. Chondri, or at least rounded spheres of nickel-iron, occur in some meteorites, though they are not common. All gradations occur from chondri which contain grains of nickel-iron to complete spheres of nickel-iron. In the stone of Renazzo such spheres have a covering of brown glass. Some of the spheres or rounded fragments also contain troilite, but troilite of itself never has been seen to form chondri. A more or less complete rim of metal is a characteristic of many chondri. The metal may occur in the form of rounded grains or as a continuous periphery. It has been suggested by Daubrée that such a rim shows that the chondrus has been subject to the reducing action of hydrogen. Besides the chondri colored black by inclusions of iron and troilite, as previously described, black chondri, which consist chiefly of maskelynite or granular plagioclase, occur in the stones of Alfianello, Chateau Renard and others. These chondri are transparent and colorless about their rim, but in the interior are totally black from inclusions of angular rounded grains, some of which are shown by their brown color to be

troilite. A gathering of grains at the center distinguishes these chondri from those previously described in which the rim was black. Besides complete chondri, fragments representing various proportions of a complete chondrus occur. These may, on

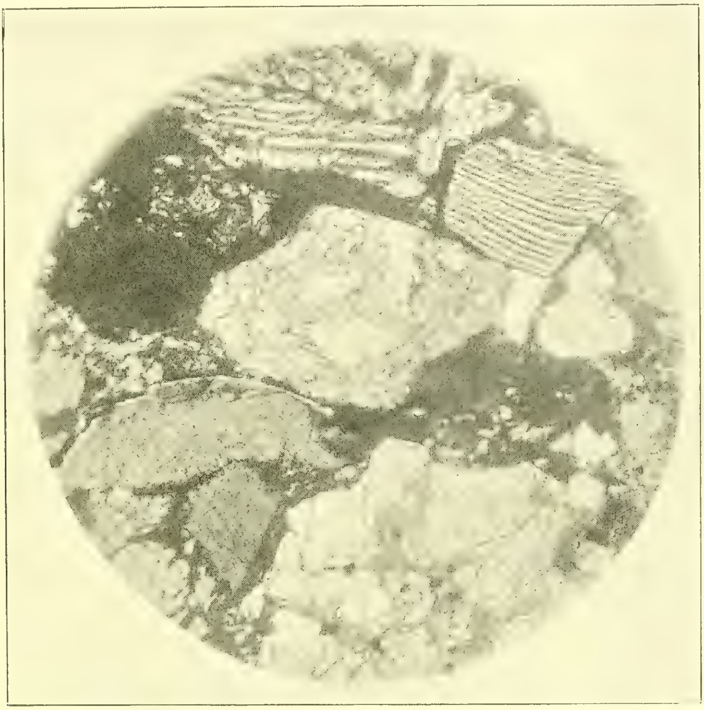


FIG. 9.—Section of the Mezo-Madaras meteorite, showing a meteoritic tuff made up of fragments of chondri. Portions of bronzite, chrysolite and nickel-iron chondri can be recognized. After Tschermak.[1]

account of their shape, be very misleading, as they may be taken for porphyritic individuals or for portions of a foreign stone if their previous chondritic origin is not recognized. Tschermak states that fragments of chondri are most numerous in the stones whose chondri have well-marked contours. So far as the association of chondri is concerned it is to be noted that chondri of more

[1] Op. cit. Tafel XIX, Fig. 4.

than one of the kinds above described usually occur promiscuously scattered through the same stone. There is no gathering of them into groups according to the minerals they contain. Occasionally one chondrus encloses another, and still more rarely two may be joined together. Broken fragments of chondri commonly occur in the same stone with complete chondri. Two fragments of the same chondrus are, however, rarely if ever found in juxtaposition. Hence there must have been considerable separation of the fragments before consolidation of the stone took place.

Theories of the Origin of Chondri and Chondritic Structures.—The conditions which have brought about the formation of chondri are not well understood, though the question has been much discussed and various hypotheses have been suggested. The views of earlier observers were to the effect that the chondri represented fragments of preëxisting rock which, by oscillation and consequent attrition, obtained a spherical form. Sorby regarded them as produced by cooling and aggregation of minute drops of melted stony matter. Tschermak considers their origin similar to that of the spherules met with in volcanic tuffs which owe their form to prolonged explosive activity in a volcanic throat breaking up the older rocks and rounding the particles by constant attrition.

Different views are, however, held by Brezina, Wadsworth, and others, these believing that the chondri have been produced by rapid and arrested crystallization in a molten mass.

Objections to theories of the first class are to be found (1) in the fact that the chondri usually have rough-knobbed surfaces instead of smooth ones, such as attrition might be expected to produce; (2) in the regularly eccentric form of most enstatite chondri, which attrition would be likely to destroy; and (3) in the fact that fragments of a preëxisting rock ought to show the constitution of the rock as a whole instead of specialized structure. Objections to theories of the second class are to be found chiefly in the clearly fragmental nature of most chondritic meteorites. It is in their variation from the surrounding ground

mass and in the eccentric arrangement of their fibers that chondri differ chiefly from the spherulites of terrestrial rocks.

SUPERINDUCED STRUCTURES

Several structures occur in meteorites which have apparently originated subsequent to the consolidation and solidification of

FIG. 10.—Slickensided surface, Long Island meteorite. Natural size. From a specimen in the Field Columbian Museum.

the mass as a whole. These may be enumerated as (1) slickensides, (2) faults, (3), bent plates, (4) veins, and (5) cleavage and joints. The first three may be grouped under the head of evidences of preterrestrial movement, but it should be stated that some authorities regard all these structures, including veins, as of terrestrial origin.

Slickensides (*Harnisch flachen*, *Surfaces de frottement.*)—These may be observed on portions of many meteorites, of which the following may be mentioned among others: Bath, Kesen, Limerick, Lixna, Long Island, Manbhoom, Mocs, Ochansk, Ställdalen, Tysnes Island, and Zavid. The slickensided surfaces may vary in area from a few square millimeters to those more than a foot square (Long Island). In many cases the surfaces have exactly the appearance of similar ones in terrestrial rocks, being smooth, shining, somewhat uneven, and more or less striated in the direction of movement. In other cases, however, they appear as dark striations on the contact surfaces, or as if the surfaces had been rubbed with a piece of graphite. The slickensided surface may be a broad peneplane with generally parallel striae, or it may be seen penetrating the meteorite in numerous narrow peneplanes following the same general directon at different levels. The surfaces do not always extend in the same direction, however, but in different directions and occasionally nearly at right angles to one another. One surface on the Long Island meteorite has in cross section the shape of a J. The polishing of the surface by the movement which has taken place often brightens the metallic grains so that they shine. Sections cut perpendicular to a slickensided surface show a flattening or elongation of the metallic grains, and even of other minerals along the course of movement,

Meunier regards the blackening seen on the surfaces as indicating heat developed by the movement, and states that the heat was sufficient to metamorphose a portion of the Mexico meteorite included between two slickensided surfaces, which he examined. The slickensided surfaces examined by the writer, however, give no evidence that the movement has been accompanied by any high degree of heat, at least enough to produce fusion, for the mineral grains along the surface are simply sharply cut off without alteration. This fact, together with the analogies given by terrestrial slickensides, indicate that the movements which gave rise to the slickensides must have taken place while the constituents of the rock were solid.

Faults.— Evidence of movement along a plane sufficient to produce well-marked faults in meteorites is not abundant. The slickensides already described prove slight movement, but how much, so far as the stony meteorites are concerned, it is difficult to say on account of the absence of bedding planes and other criteria of measurement. In the iron meteorites, however, the bands of the Widmanstätten figures afford a means of measurement. Sections of several such meteorites, viz., Bridgewater, Carlton, Magura, Puquios, and Descubridora, in this way exhibit faulting. In the Puquios meteorite the faulting is of somewhat complicated character, the kamacite bands showing slight dislocation in various directions. The largest fault extends the entire length of the mass, and has a throw of 1/8 of an inch (3 mm). Some crushing and branching also appears along this line of faulting. Other less extensive lines of faulting occur. The amount of throw seen in the Descubridora meteorite is more extensive than in the Puquios, being a distance of from 1/4 to 1/2 an inch (6 to 12 mm). Owing to the toughness and tenacity of iron meteorites at ordinary temperatures, Howell has suggested that such faulting could only have been produced when the mass was highly heated, as, for instance, in its passage near the sun. He found that a piece of the Toluca meteorite, although very tough when cold, would crumble under the hammer when heated to a white heat. He states that it also seems necessary to assume a contact with some other body, as well as a heating, in order to account for the faults. In opposition to this view by Howell the faulting is believed by Brezina, according to a label in the Vienna Museum, to have been the result of the impact of the mass on the earth.

Bent plates.— These are somewhat allied to faults, there having been differential motion in the mass, but not a sufficient amount to produce fracture. Naturally, they are to be noted only in the iron meteorites. Carlton, Glorieta Mountain, Jamestown, Ranchito, and Toluca are some of the meteorites in which they have been observed. The bent plates appear upon an etched surface as curved Widmanstätten figures. They

never characterize an entire mass, so far as I am aware, but only portions, and occasionally but a small portion of a single mass. The amount of curvature is not great, rarely if ever exceeding 10^{mm} in 50. A single plate never has more than one direction of curvature, though it is often straight for some distance at one end and curved at the other. With reference to each other, however, the directions of curvature of individual plates may be quite different. Like faults, the bending is referred by Brezina to the result of the impact of the meteorite upon the earth.

Veins (*Adern, Filons, Veines*).—These occur in many stony meteorites, in fact in a sufficient number to characterize seven of the thirty-seven groups into which Brezina divides stony meteorites. The veins may vary in width from a mere line to 19 millimeters (Mocs). An even greater dimension is indicated by the size of single stones from the Pultusk and Mocs showers, which seem to be of a substance like that of the veins. The veins penetrate the stones now in a nearly straight direction and now in a more or less tortuous one. Sometimes they are single, then again branched, and again ramify to such an extent as to form a network. They are rarely uniform in width for any appreciable distance. On the contrary, they widen and narrow very irregularly, often forking so as to enclose portions of the mass and then meeting again. The Bluff meteorite shows two systems of veins crossing one another at angles of about 45°. The narrower of these is uniform in width and was observed over a plane 4 × 15 inches in extent. The wider varies much in width and is less extensive.

In color, veins are dark, usually black. The substance filling them is black, opaque, brittle, and of a semi-glassy character. In polarized light it appears amorphous and isotropic. It often includes splinters of the adjoining stone and little spheres of nickel-iron and troilite. Along the walls are often seen delicate metallic foliae, lying parallel to the direction of the veins. These appear in cross section like delicate threads. From the nickel-iron grains threads often run out in a direction

across that of the vein, and these may pass into empty clefts. In many portions of the stone of Chantonnay narrow, irregular, open fissures occur. Some of these have begun to be filled by matter that has flowed in from the surface, but it has penetrated only to a depth of a few millimeters. The vein substance

FIG. 11.—Cross section of a vein of one of the Mocs meteorites. The vein mass appears as a broad black band through the center. It is in part intermixed with the adjoining groundmass and in part has well defined walls. The gray spots are spheres and lumps of nickel-iron illuminated by reflected light. The branching of some of these into clefts, one of which is still open, is of interest. × 20. After Tschermak.[1]

usually has fairly well-defined walls, but on the other hand may gradually pass into the body of the meteorite. In the stone of Goalpara, which is coarsely porous, a black, vein-like substance forms the walls of the pores, makes up the groundmass, and

[1] Op. cit. Tafel XXII, Fig. 2.

penetrates into the minutest fissures. Again, the groundmass of the stone of Richmond is a black, half glassy substance which occupies the spaces between the chondri and spreads itself into their interstices. Thus the veins may occur as mere apophyses of a black groundmass. In fact, apparently the same substance forms veins in the meteorites of Mocs, a cement in the stone of Orvinio, and the entire groundmass of such carbonaceous meteorites as Cold Bokkeveld. That the substance is exactly the same in all these cases cannot be regarded altogether proved as yet, however. An analysis by Whitfield of the vein substance of the Bluff meteorite showed it to be very similar in composition to the mass of the stone. Tschermak states that the vein substance of the Goalpara stone consists of a network of iron, holding troilite, carbon, and a glassy substance found to be decomposed by acids. The substance of the black veins of the Chantonnay meteorite Meunier regards as consisting of a silicate of iron. An interesting experiment performed by him in this connection was that of heating meteorites of the group to which he gives the name of Aumalite, to redness without access of air. The meteorite then became black, of lighter specific gravity, and increased in hardness and toughness. In other words, it became a substance which he regards as exactly similar to that of the veins of Chantonnay. He regards the presence of this substance in the stone of Chantonnay, therefore, as proof that the meteorite had undergone heating or metamorphism before its entrance into the earth's atmosphere.

So far as the general appearance of the black veins is concerned, it may be said with Tschermak that they give the impression that the substance of the meteorite at some time underwent fissuring and that a fused liquid was absorbed into these fissures. The phenomenon must have differed somewhat from that of the injection of fused lava into the interstices of terrestrial rocks, since the substance of the vein mass agrees so closely in composition with that of the substance of the meteorite.

Vein-like filaments.—In passing from the iron to the stony

meteorites every gradation may be traced from metallic masses in which the silicates appear as porphyritic ingredients, through those appearing to be made up of interwoven constituents, to those in which the metallic constituents appear as isolated grains. In several of the latter class of meteorites (Farmington, Crab Orchard Mountains, Bluff) long, branching, metal filaments are seen to be associated with the isolated grains.

In the view of the present writer, these are filamentous phases of the structure of the metallic portions of the meteorite. Other meteorites, of which those of Honolulu, Mocs, and Pultusk may serve as illustrations, have what appear to be metallic veins when seen in cross sections. When cleft along the vein, however, these prove to be slickensided surfaces along which the metallic grains of the meteorite have been drawn or flattened out by the movement. These vein-like structures are clearly of different character from those just described. They sometimes give a well-marked appearance of a vein outlined on the crusted surface of a meteorite. This is owing to the fact that resisting fusion more than the stony matter they stand out in relief.

Cleavage and joints.— Most of the cubic irons are characterized by a complete cubic cleavage. This cleavage doubtless indicates that the masses are crystal individuals. Huntington has described cleavage planes as passing through some of the octahedral irons independent of the octahedral structure. It is probable that these, as well as cleavage along the octahedral planes often noted, are separation planes resulting from weathering.

Few stone meteorites are of sufficent size to exhibit a jointed structure if it existed. Meunier has called attention to an elongated depression in one of the L'Aigle stones which he regards as marking the position of a former joint plane. The Long Island meteorite, the largest stone meteorite known, is cut by three large division planes which perhaps represent joint planes. Two of them are at right angles to one another, while the third, somewhat broken, is nearly at right angles to the other two. The great irregularity of form of most meteorites,

however, would seem to indicate that division planes were lacking in the masses from which they have separated.

SYNTHETIC EXPERIMENTS IN THE REPRODUCTION OF STRUCTURAL DETAILS

Fouqué and Levy have succeeded in reproducing, so far as the component minerals were concerned, mineral aggregates corresponding to several types of meteorites. Among meteorites not containing feldspar, aggregates were produced corresponding to the meteorite of Rittersgrün, which is made up of chrysolite, enstatite, a magnesian pyroxene, and iron. Among meteorites containing feldspar, aggregates were produced corresponding to those of the class known as Eukrites, which are made up of anorthite, enstatite, and pyroxene, and of the class made up of anorthite, enstatite, and chrysolite. These were all produced by cooling from fusion, different mixtures of silica, alumina, magnesia, carbonate of lime and iron oxide. The chief difference noted by these authors between these products and meteorites of corresponding chemical composition is one of structure. The artificial products were of a marked granitoid texture, while most meteorites have as strongly brecciated or tuffaceous character. It is also true that the iron in the artificial products was in the form of oxide. This could, however, easily be reduced to the metallic state by exposing the mass to the action of reducing gas at a red heat for two hours. Previous to the experiments of Fouqué and Levy stone meteorites of several types had been fused by Daubrée and the resulting cooled products examined. The products resembled the original masses in some respects, but in many respects differed. Thus chrysolite and enstatite separated in a sort of liquation, the chrysolite forming a thin layer above, while the enstatite crystallized below in the form of long needles. Moreover the iron grains took spherical forms rather than the irregular ones which characterize meteorites. Daubrée therefore concluded that the mode of formation of meteorites differed from purely igneous fusion. The needles of enstatite artificially obtained

seemed analogous in his opinion to the needles formed on the surface of freezing liquids, while the grains seen in meteorites seem more like the forms of frost or snow formed by the immediate passage of water vapor to the solid state. This conclusion led to a number of experiments by Meunier with vapors of silica, magnesia, etc., for the purpose of forming in this manner if possible mineral aggregates resembling the meteorites The results so far obtained have been chiefly negative, though the experiments are still being conducted. A prominent feature lacking from the results of the experiments with vapors is the glass so abundant in meteorites. This is obtained in quantity however in the products cooled from fusion.

Many efforts have been made to reproduce Widmanstätten figures but they cannot be said to have met with much success. As it is held that the Widmanstätten figures indicate slow cooling from fusion, Sorby fused together iron, nickel, and other constituents of an iron meteorite, and allowed the mass to cool very slowly. On examining an etched surface with a lens, minute lines were seen which recalled the Widmanstätten figures but the appearance as a whole, he states, was very different. The mass was then kept for a long time at a temperature just below that of fusion but the resulting product was less like meteoric iron than that previously obtained. Daubrée fused a portion of the Caille meteorite in a crucible of clay, then allowed the mass to cool slowly. The resultant mass showed a crystalline structure but all trace of the former Widmanstätten figures was lost. On fusing a mixture of iron, nickel, troilite, and silica, he obtained a product showing dendritic figures. On fusing a mass of iron, nickel, and iron phosphate together, a mass having a reticulated structure with angles showing dodecahedral crystallization was obtained, The structure of this mass approached more nearly the Widmanstätten figures than any obtained in any other way, and it is sometimes stated that true Widmanstätten figures were produced. As Cohen remarks, however, the statement needs to be supported by figures and specimens. The same may be said of Meunier's

statement that he found Widmanstätten figures on a mass obtained by reducing iron and nickel chlorides from their vapors. J. Lawrence Smith states that he obtained Widmanstätten figures on a button of iron which cupelled from a mixture of iron silicate and chalk heated to fusion for from 15 to 20 minutes in oxygen in excess. If the excess of oxygen was essential to the success of this experiment, it was a condition certainly wanting in the formation of the iron meteorites.

It is true of chondri as of Widmanstätten figures that they have not yet been successfully reproduced by synthetic methods. Especially has it been found impossible to reproduce the structure exhibited by many enstatite chondri, of fibers radiating from a point eccentrically placed with reference to the center. Meunier has obtained from vapors of silicon chloride and magnesium acicular crystals of pyroxene which he recently showed the writer, which radiate in a fashion recalling the above-mentioned chondri. They cannot, however, be said to be in any sense reproductions of the chondri, and they are moreover a monoclinic pyroxene. Perhaps the nearest approach in form to these structures has been obtained recently by Brauns in crystals obtained by cooling sulphur. The forms were produced either by suddenly cooling a strongly heated preparation of sulphur or by slowly cooling and suddenly shaking it. Such results suggest that the peculiar structures of chondri indicate special conditions of cooling or percussion to which the mass has been subjected. If these conditions could be reproduced, chondri could, perhaps, be formed synthetically. It may be suggested that immediate contact with the intense cold of space, a condition which has not yet been experimentally fulfilled, is perhaps the force which has given chondri their peculiar form.

NOTE.—For further study and for lists of references the following works may be consulted: Meteoritenkunde, Heft I, E. COHEN, Encyclopedie chimique, Tome II, Meteorites, S. MEUNIER; Die mikroskopische Beschaffenheit der meteoriten, G. TSCHERMAK.

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EDITORIAL

A GEOLOGICAL and geographical excursion in the North Atlantic is planned for the summer of 1901. Conditionally on the formation of a sufficiently large party, a steamer of about 1000 tons, specially adapted for ice navigation, and capable of accommodating sixty men, will leave Boston on or about June 26 and return to the same point on or about September 20. The main object of the voyage will be to offer to the members of the excursion party opportunity of studying the volcanic cones and lava fields, the geysers, ice-caves and glaciers of Iceland, the fiords and glaciers of the west coast of Greenland, and the mountains and fiords of northern Labrador. Some attention will be paid to the hydrographic conditions of the waters traversed. Botanists, zoölogists, ornithologists, mineralogists, and those interested in other branches of natural history may pursue independent studies. A hunting party may take part in the expedition; it could be landed for a fortnight or three weeks in Greenland and for about the same period in Labrador.

An inclusive fee of $500 for each member will be charged, $250 to be deposited with the leader of the expedition on or before March 15, the balance to be paid or on before June 1.

The trip will be under the direction of Dr. R. A. Daly, of the Department of Geology and Geography, Harvard University, Cambridge, Mass. Applications for membership should be addressed to him.

Reviews.

Zeiller's *Flora of the Carboniferous Basin of Heraclea: An Illustration of Paleozoic Plant Distribution.*

At a meeting of the Biological Society of Washington in November 1897, the writer exhibited a small number of specimens of Carboniferous plants from Asia Minor, and called especial attention to the precise agreement in detail of several of the species with the corresponding types in our American Coal Measures. Particular emphasis was laid on the remarkable geographical distribution of plant species in Middle Carboniferous time, as to which the material in hand constituted new evidence. This striking agreement in exact form between the American and Asiatic species could not fail to arouse in paleobotanists the keenest interest in the publication of the results of the study of the southeastern flora by Professor Zeiller, to whose courtesy the writer was indebted for the above mentioned specimens.

Professor Zeiller's study of the Carboniferous flora of Heraclea[1] (Eregli) is an admirable example of stratigraphic paleobotany. To the stratigrapher who is unacquainted with the progress made of late years in the differentiation and recognition of the various Carboniferous floras of the Old World, and of their utility as means of correlation, it is an instructive illustration. To paleontologists this close, critical work is especially valuable for the light it throws on the areal distribution of identical species and on the identity and regularity in sequence of the floral associations characteristic of the several stages.

The fossil plant material, chiefly collected by M. Ralli, was obtained from several isolated areas in two of which the structure is particularly complicated, the terranes being diversely and frequently faulted, or even shattered. The collections from these areas are found by Zeiller to embrace 122 species which, when grouped by localities, very distinctly indicate three stages of the Carboniferous, which M. Ralli also is able to recognize stratigraphically in portions of the

[1] Étude sur la flore fossile du bassin houiller d'Héraclée (Asie Mineure). R. Zeiller, Mém. Soc. géol. Fr., Paléontologie, mém. 21, Paris, 1899, 91 pp., 6 pl.

territory, although the complex structure hardly admits of correlation without paleontological aid.

In the following paragraphs the general paleontological features of the three stages will be outlined, together with the correlations proposed by Zeiller. To this will be added comments on certain of the Heraclean plant types with some suggestions as to the relations of the Heraclean Carboniferous floras to those of eastern North America.

A. The lowest of the three paleobotanical stages recognized by Zeiller in the material examined is that of Aladja-Agzi. In the collections from several localities representing this stage in the various areas, he finds :[1]

*Sphenopteris dicksonioides,** *S. bermudensiformis, S. Larischi,** *S. divaricata,** *Rhodea* cf. *Stachei, Diplotmema dissectum, D. elegans,** *Adiantites oblongifolius,** *Pecopteris aspera, Archæopteris*, sp., *Cardiopteris polymorpha, Sphenophyllum tenerrimum,** *Asterocalamites scrobiculatus,** *Calamites ostraviensis, C. ramifer,** *Lepidodendron acuminatum,** and *Lepidophyllum lanceolatum.*

Two additional species are described as new, viz.: *Sphenopteris bithynica* and *Sphenophyllum Sewardi.*

Of the previously described species, all in the above list, with the exception of the undeterminable *Archæopteris* and the *Lepidophyllum lanceolatum* are also present in the Ostrau-Waldenburg (Upper Culm) stage of Silesia, with which the Aladja-Agzi flora is correlated by Professor Zeiller. The species marked by the asterisk (*) in the above list are also recorded from the Appalachian Pottsville, with whose lower portion the Ostrau-Waldenburg beds are probably, in part, at least, contemporary, as has already been elsewhere[2] indicated. Of the remaining plants *Sphenopteris bermudensiformis* is evidently closely related to a form from the Pottsville referred to *S. asplenioides*; while the specimens figured as *Diplotmema dissectum* appear to find a corresponding form in the latter formation. *Sphenopteris bithynica* seems to be extremely close to *S. subfurcata* Dn. from the supposed "Middle Devonian" [Pottsville] at St. John, N. B., while *Sphenophyllum Sewardi* stands in a similar relation to *S. tenue*[3] from the Welch

[1] The nomenclatural orthography in the following list is that used by Professor Zeiller.

[2] Bull. Geol. Soc. Amer., Vol. VI, p. 320, 1895. See also: Twentieth Annual Rept. U. S. Geol. Surv., Pt. II, p. 912.

[3] Twentieth Annual Rept. U. S. Geol. Surv., Pt. II, 1900, p. 900, Pl. CXCI, Figs. 6, 7.

formation (Middle Pottsville). With reference to the *Lepidophyllum lanceolatum* listed above, I would add that the specimen figured by Professor Zeiller would seem to agree with the *L. Campbellianum* described by Lesquereux from the Pottsville. The latter is much more slender, acute and narrowed toward the relatively small sporangiophore than is the quite distinct type, from the higher Coal Measures, identified by Lesquereux as *L. lanceolatum* L. and H. *Cardiopteris polymorpha* has not in this country been found in beds so high as the Pottsville, though it is present in beds of Chester age.

B. Above the Pero bed at Kilimli, whose flora belongs to the Aladja-Agzi stage, and separated from that bed by a conformable series of sandstones and conglomerates 90 meters in thickness lies the Sinork coal, with which are found *Mariopteris acuta*, *Asterophyllites grandis*, and *Lepidodendron Veltheimi*. The first two named are characteristic of the Westphalian of Europe, while the third is present in the Culm as well. The more exact place of this florula is in the lowest of the three stages of the Westphalian. All three species are present also in the lower group of the Kanawha formation in West Virginia. The plants accompanying the coals mined at Coslou (Kosloo) as well as those from a number of other localities, many of which are in faulted blocks, belong to the same stage as the Sinork plants, though some of the localities are evidently at a lower horizon in that stage than others.

The entire flora from this stage includes: *Sphenopteris obtusiloba**, *S. Schillingsi**†, *S. Baeumleri*, *S. Frenzeli*, *S. schatzlarensis*, *S. Sauveuri**†, *S. Crepini**†, *S. Laurenti**†, *S. Hoeninghausi**, *S. tenella**†, *S. Aschenborni*, *S. Schwerini*, *S. Karwinensis*, *S. Vüllersi*, *S. bella*, *S. Sternbergi*, *Rhacopteris subpetiolata*, *Palmatopteris furcata**, *P.* cf. *elegantiformis**, *Mariopteris muricata**†, *M. acuta**†, *Pecopteris plumosa**†, *P. aspera*, *P. pennæformis**, *Alethopteris Davreuxi*, *A. decurrens**†, *A. Lonchitica**†, *Lonchopteris Eschweileriana*, *Nevropteris gigantea**†, *N. Schlehani**†, *N. heterophylla**, *Sphenophyllum cuneifolium* (old form)*†, *Calamites Suckowi**, *C. undulatus**(?), *C. Cisti**, *C. ramosus**, *C. Schützei*, *C. distachyus*, *Asterophyllites grandis**†, *A. equisetiformis**, *Annularia galioides**, *A. Radiata**†, *Radicites columnaris**, *Lepidodendron lycopodioides*, *L. aculeatum**, *L. dichotomum**, *L. obovatum**†, *Lepidophloios laricinus**, *Lepidostrobus Geinitzi**, *Lepidophyllum lanceolatum**, *Sigillaria elegans**, *S. elongata**, *S. Schlotheimi**, *S. scutellata**, *S. Davreuxi**, *S. Boblayi*, *S. mamillaris**, *S. germanica*, *Stigmaria ficoides**, *Cordaites principalis**, *and Dorycordaites palmæformis.*

The new types described from this stage are *Sphenopteris Ralli*, *S. heracleensis*, *Potoniea adiantiformis*, *Calamophyllites vaginatus*, *Phyllotheca Ralli*, and *Sigillaria euxina*.

All but six of the species listed above are present in one or more of the European basins. The flora of the lower horizon is referred to the lowest of the three stages of the Westphalian, while that of the slightly younger horizon is regarded as overlapping on the lower or transition portion of the middle stage.

It is impracticable to discuss in this place the relations of the large and interesting flora from this stage to the floras of the United States. I have, however, marked with the asterisk (*) those species that are recorded from the Carboniferous of North America.

The percentage of identical species is undoubtedly fully as large as that marked in the list. Of the American representatives among the fern species the greater portion are present either in the Kanawha formation of southern West Virginia and Kentucky, or the upper portion of the Pottsville formation. In fact the flora of the lower horizon in the Coslou group is clearly comparable to the topmost Pottsville and earlier Kanawha plant associations. The flora of the upper horizon of the Coslou group has little in addition besides the Sigillarias that is common to the Allegheny series, and it, too, is distinctly older than that series, though it appears hardly so typical as the other flora of the Lower Kanawha group. The surprisingly close relations of the flora of the Coslou stage to the uppermost Pottsville, and particularly to the Lower Kanawha flora will be better understood when the detailed studies of the latter floras are published. Suffice it for the present to say that the species marked by the (†) in the above list are, so far as I have observed, peculiar to and characteristic of this combined portion of the Appalachian Upper Carboniferous section.

A few among the more important species closely related to American types deserve special mention: *Sphenopteris Vüllersi* is very close to a variety of *S. furcata* from the Southern Anthracite field; *S. Sternbergi* to *Aloiopteris* (*Sphenopteris*) *georgiana* of the Pottsville; and *Alethopteris Davreuxi* differs but little from the latest phase of *A. grandifolia*. My remarks on the *Lepidophyllum lanceolatum* in the lower stage probably apply equally to the Coslou specimens.

As *Potoniea* Zeiller describes a type of fructification whose fleshy adiantiform divisions are studded or fringed with fusiform bodies suggesting the sporangia of *Crossotheca* (*Sorocladus* of Lesquereux). It is

regarded by him as belonging more probably to a fern, though it is possibly gymnospermous. *Phyllotheca Ralli* is an extremely interesting type whose fructification appears to be very close to that of the living *Equisetum*, while the leaf sheath, suggestive of *Annularia radiata*, is very similar to that of an undescribed species from the lower Kanawha group of West Virginia. The genus *Phyllotheca*, which is present in the Indo-Australian *Glossopteris* flora (Permo-Carboniferous), and which for a long time was supposed not to have appeared in Europe until the Jurassic, has later been described from the Permian and is now known in the Coal Measures of both Europe and America.

C. The upper or Caradons stage in the Heraclean basins is represented by many localities whose largely common floras evidently lie in or near the same stage. Its flora includes: *Sphenopteris* (*Crossotheca*) *Crepini**, *S. Bronni**, *Palmatopteris alata**, *Pecopteris Miltoni**, *P. oreopteridia**, *P. unita**, *P. Roehli*, *P. plumosa**, *P. Pluckeneti**, *P. Newberryi**, *Alethopteris Serli**, *A. Grandini**, *Odontopteris britannica**, *O. Reichiana**, *Nevropteris Scheuchzeri**, *N. heterophylla**, *N. rarinervis**, *N. tenuifolia**, *Linopteris obliqua**, *L. Münsteri*, *Caulopteris patria*, *Ptychopteris macrodiscus*, *Sphenophyllum cuneifolium**, *S. emarginatum**, *S. oblongifolium*, *S. majus**, *Annularia stellata**, *A. sphenophylloides**, *Lepidodendron Jaraczewski*, *Sigillaria tessellata**, *Cordaites borassifolius**, *Cordaites principalis**, *Cordaicarpus congruens**, and *Samaropsis fluitans**.

Five species, *Sphenopteris Limai*, *Pecopteris Armasi*, *Alethopteris pontica*, *Linopteris elongata*, and *Plinthiotheca anatolica*, have not been found elsewhere.

In the above list the asterisk (*) denotes an American distribution for the species, most of which are familiar to those geologists who have observed the plants of the Coal Measures in the northern bituminous basins. Among them *Pecopteris Miltoni*, *P. unita*, *P. Pluckeneti*, *P. Newberryi*, *Alethopteris Serlii*, *A. Grandini*, *Odontopteris britannica*, *O. Reichiana*, *Nevropteris Scheuchzeri*, *N. rarinervis*, *Linopteris obliqua*, *Sphenophyllum emarginatum*, *S. oblongifolium*, *S. majus*, *Annularia stellata, and A. sphenophylloides* are characteristic of the Allegheny series and higher Coal Measures.

The flora of the Caradons stage contains a mingling of uppermost Westphalian species with Stephanian types. This flora is correlated by Zeiller with that of the stage of the Radstock Series in England, the Geislaütern beds in the Saar region, the "middle series" in the

Zwickau basin of Saxony, the Schwadowitz beds in lower Silesia, and with the Mazon Creek, Illinois, flora of the United States.

The flora of Mazon Creek seems to find its place in the Kittanning group of the Pennsylvania basins, and probably near the horizon of the Middle Kittanning coal. The presence of certain species, particularly of *Odontopteris*, of abundant *Linopteris obliqua*, of *Pecopteris Miltoni*, of *Alethopteris Grandini*, and of *Sphenophyllum oblongifolium* in the Heraclean flora leads me to conclude that the Caradons material was derived from beds slightly later than the Mazon Creek horizon, or perhaps as high as the Freeport group, which is next above the Kittanning group, though also within the Allegheny series. *Sphenopteris Crepini*, which is probably present in the upper Kanawha group, is very closely related to *Sphenopteris sagittata* from Mazon Creek and *S. ophioglossoides* from the Des Moines series of Missouri. *Sphenopteris Bronni*, *Nevropteris tenuifolia*, *Sphenophyllum cuneifolium* and *Cardiocarpus congruens* are perhaps the only species whose presence in the Caradons flora argues, on the one hand, for a horizon lower than that of Mazon Creek. The far more important and abundant evidence of the fern elements is, on the other hand, for a rather later date.

The most interesting of the plants newly described from the Caradons beds are *Pecopteris Armasi* and *Plinthiotheca anatolica*. The former appears to form a connecting link between *Pecopteris* and *Callipteridium*. *Plinthiotheca* is represented by thick, fleshy peltate or cyclopteroid leaves, radiately densely vascular and covered by small capsules arranged in fours in contiguous squares. These capsules are regarded by Professor Zeiller as sporiferous, rather than polleniferous; and the type is therefore tentatively ranged by him with the ferns instead of with the Doleropteroid gymnosperms. The examination of Zeiller's figures and a careful comparison of the types of *Dolerophyllum pennsylvanicum* in the Lacoe collection convinces me that the Heraclean type is generically identical with that described from Pennsylvania by the late Sir William Dawson.[1]

The generally close agreement mutually between Professor Zeiller's correlations of the Heraclean floras in Europe or this country with my own correlations of the Middle Pottsville, the Lower Kanawha, and the Allegheny series well illustrates the marked paleobotanical differentiation of the stages, and the regularity of the sequence, as well as the extraordinary geographical distribution of the several Middle

[1]Can. Rec. Sci., Vol. VI, p. 8, 1890.

Carboniferous floras. Of the 122 species contained in the collections from the three Heraclean stages not more than eleven are unknown in Europe or America.

David White.

Géologie et minéralogie appliquées. Les minéraux utiles et leur gisements. Par Henri Charpentier. Pp. 643 + xi; illustrated, 12mo. Paris, 1900.

This volume forms a part of the *Bibliothèque du Conducteur de Travaux Publics* of France, and is published under the auspices of the ministers of public works, of agriculture, of public instruction, of commerce and industry, etc. Its title-page is followed by the *Comité de patronage*, a list of thirty-nine prominent government officials, and by the editing committee with twenty-seven additional and equally distinguished names; then comes a preface written by the chief engineer of mines.

A work upon economic geology, introduced with these impressive formalities and distinguished approvals, one naturally expects to find of unusual merit and importance. The general plan of the work is very like that followed by Fuchs and De Launay in their large and excellent *Traité des Gîtes minéraux et métallifères*, published in 1893; but this work by Charpentier is evidently intended to be more elementary and for a less instructed class of readers.

The first seventy-four pages are devoted to general geology, mineralogy and paleontology. In the second part the economic-geologic subjects are taken up in the following order:

(1) Building materials, (2) Metallurgical minerals, (3) Carbon and its compounds, (4) Fertilizers, (5) Miscellaneous minerals, (6) Rare metals, (7) Precious stones.

These topics are properly subdivided and treated separately, and at the end of each discussion is a list of bibliographic references that varies in length from one to thirty or more titles chronologically arranged. The economic geology of France naturally occupies the first place, but those of other countries are also treated at such length as to lead one to suppose that the book was expected to be useful outside of France.

The bibliography given after each topic will appeal to busy readers as especially useful. In the preface it is stated that this *bibliographie fort complète* will do away with tiresome searching for literature by

those who want to go deeper into the subjects treated. We venture to hope that the busy reader will be more fortunate in the use of these references than we have been. To one somewhat acquainted with the general literature of economic geology these lists are more remarkable for what they do not than for what they do contain. What must geologists and mining engineers in any part of the world think of bibliographies with such omissions as the following? Under Building Stones no reference is made to Merrill; under Copper no mention of Whitney, Irving, or Wadsworth; under Zinc no mention of Winslow; under Phosphates and Manganese no mention of Penrose; under Quicksilver no reference to Becker; under Petroleum and Natural Gas no mention of Carll or Orton; under Silver no reference to Emmons; and under Diamonds no mention of the writings of Derby.

The references that are given are often quite irrelevant, and sometimes wrong. For example under the list upon "combustible minerals," p. 405, is this: "1871. Hartt. *La faune carboniferienne du Missouri* (Neues Jahrb., p. 63)." The place cited contains a note by Louis Agassiz upon the Carboniferous fauna found by Hartt in South America. There is not a word about Missouri, and as a matter of fact there is no coal in the South American Carboniferous area mentioned by Hartt. On p. 406 is this: "1878. Derby. *Le carboniferien au Missouri* (Neues Jahrb., p. 663)." There is no such article at the page cited, and I much doubt Professor Derby's having written such an article at all. On p. 538 the bibliography of kaolin gives a title by Fontannes. Upon looking up the article cited it is found to contain nothing about kaolin. In addition to these defects the typographical errors in the references render many of them worthless.

The book seems to be intended for a sort of *vade mecum* on economic geology, and as such it will be found helpful. It is of convenient size and neatly bound in flexible leather.

J. C. BRANNER.

Handbuch der Seenkunde. Allgemeine Limnologie. Von DR. F. A. FOREL. Stuttgart: Verlag von J. Engelhorn.

This volume is one of the series of useful geographic handbooks published under the general editorship of Professor Dr. Friedrich Ratzel. It brings together in concise, comprehensive, and readable form the general principles of limnology.

The first part of the volume is devoted to a discussion of lake basins, the discussion covering the origin of lake basins and of lakes, the obliteration of the basins, and the deposits made in them.

The second and larger part of the volume deals with the waters of lakes. Here are included (1) Hydrology — supply and waste; (2) Hydraulics, including the pressure of the water, the levels of lakes, their changes, permanent and temporary, rhythmic and non-rhythmic, the waves, seiches, currents, etc.; (3) Chemistry, including the comparative study of the waters flowing into the lakes, that in the lakes, and that flowing from them. Comparisons are also made with sea water; (4) The temperature of lakes, including a discussion of surface temperatures, their areal and periodic variations, comparisons of the temperature of the surface water with that of the overlying air, and the temperature of the sub-surface waters; a section is also given to the freezing of the lake water; (5) Optics, including the penetration of light, the color of the water, reflection, refraction, etc., under various conditions; (6) The biology of lakes. Besides the more obvious topics considered in this chapter, a section is given to the origin of lacustrine societies, and another to the physiology of lacustrine organisms.

In an appendix is given an outline for the prosecution of lacustrine studies, and also a bibliography.

The volume is the best brief compendium on the subject with which it deals. R. D. S.

A Preliminary Report on the Artesian Basins of Wyoming. Bulletin 45 of the Wyoming Experiment Station. By WILBUR C. KNIGHT.

While this report is primarily a consideration of the artesian basins of the state, its first part is devoted to a summary of existing knowledge concerning the geology of the state. The following systems of rocks are represented: Archean, Algonkian, Cambrian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Eocene, Oligocene, Miocene, and Pleistocene.

The Archean is found at various points in the mountain ranges. The Algonkian has a similar distribution, with a total maximum thickness, including some igneous rock, of 20,000 feet. Following the deposition of the Algonkian rock were great disturbances and elevations, followed by a prolonged period of erosion. The late Cambrian

and late Ordovician periods are represented by relatively thin formations, chiefly of limestone. The Ordovician is found only in the northern part of the state, and the Devonian, so far as now known, only in the northwestern. As elsewhere in this part of the United States, the Devonian seems to rest conformably on the Ordovician. The Carboniferous is more fully represented than the preceding systems. The Lower Carboniferous is found only in the northern half of the state, while the Upper is more widespread. Limestone is the dominant rock. The Permian occurs in the Laramie, Big Horn, and Wind River mountains. It has but slight thickness, 200 feet or so, but has the fauna characteristic of the period.

The Mesozoic systems are much more fully represented, being in the aggregate 20,000 to 30,000 feet thick. They are in general conformable on the Paleozoic.

The Triassic system is represented by the Red Beds, which are gypsiferous and without fossils. The Jurassic system is represented by a marine division, the Shirley formation, overlaid by a fresh-water division, the Como formation. Both formations are referred to the later third of the Jurassic period. No special reasons are given for assigning the Como to the Jurassic, rather than to the Lower Cretaceous. This formation is said to have covered most, if not all of the state, and its character is such as to indicate marshy and lacustrine conditions.

The Cretaceous formations are the most extensive in the state. They cover about 50,000 square miles, and the thickness is 20,000 to 25,000 feet. The following formations are present: The Dakota, Bear River, Fort Benton, Niobrara (which contains some chalk), the Fort Pierre and Fox Hills formations, which together are, at the maximum, something more than two miles thick, and the Laramie, which has a thickness of about one mile. The Montana division (Fort Pierre and Fox Hills) contains some oil and coal, and the Laramie much coal. The Fort Union beds are also placed with the Cretaceous, with a question.

The areas of the Tertiary rocks are characterized by the Bad Land topography. The Eocene is represented by the Bridger, Green River, and Wasatch beds; the Oligocene by the White River beds; the Miocene by the Loup Fork. The Eocene beds have an aggregate thickness of 3500 feet, the White River of 1500, and the Loup Fork of 500. Pliocene beds are not known.

During the Pleistocene there were very considerable glaciers in the Wind River, Absaroka, Shoshone, Big Horn, and Medicine Bow mountains, as well as in the Yellowstone Park. Glaciers also reached the state line from the Uinta Mountains. No subdivisions of the glacial period have been made out.

The report is accompanied by an uncolored geological map, which is, we believe, the first geological map of the state which has been published.

R..D. S

Die vierte Eiszeit im Bereiche der Alpen, von ALBRECHT PENCK. Vorträge des Vereines zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. XXXIX. Jahrgang. Heft 3, 1899.

In this little pamphlet, as the title implies, Dr. Penck recognizes four distinct epochs of glaciation (instead of three as heretofore) in the Alps. The additional epoch which is here added belongs to the earlier rather than to the later stage of the glacial period. The differentiation of these several epochs is based primarily on the topographic distribution of the deposits made by the waters which flowed from the ice, the deposits of the several epochs being so disposed as to show very considerable periods of erosion between the periods of fluvio-glacial deposition.

This paper is of interest in that it helps to bring the phenomena of this somewhat isolated area of glaciation into still closer correspondence with the phenomena of the greater areas of glaciation in northwestern Europe and North America.

R. D. S.

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THE

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THE CLASSIFICATION OF THE WAVERLY SERIES OF CENTRAL OHIO[1]

INTRODUCTION

PERHAPS it may seem strange that a consideration of the classification of the Waverly series[2] is proposed after the thorough investigations of the Ohio Geological Survey directed by Doctors Newberry and Orton. Their investigations gave the world the main facts concerning the economic and general geology of the state and the names of Newberry and Orton will be associated for all time with the geology of Ohio as those of Mather, Emmons, Vanuxem, and Hall are with that of New York, and Henry D. Rogers and Lesley with that of Pennsylvania. It is true of geology, however, as of other sciences that the scope is constantly widening so that a restatement of facts or, perhaps, another investigation of the whole subject, aided by later discoveries, may be required. At present this is especially true with reference to the stratigraphical geology of America. During the lifetime of Dr. Newberry the nomenclature of

[1] Published by permission of Professor Edward Orton, Jr., state geologist of Ohio. Presented to the tenth meeting of the Ohio State Academy of Science, Columbus, December 27, 1900.

[2] Series is used in the sense proposed by the International Congress of Geologists. See Work Inter. Cong. Geologists, 1886, p. 50; GILBERT, in Proc. A. A. A. S., Vol. XXXVI, 1888, p. 186; and Congrès Géologique International (8[e] Session), Procès-verbaux des Séances, 1901, p. 34.

geological formations was not closely scrutinized and there were very few clearly defined rules governing the naming of the various geological divisions. In general, the names referred to some locality in which the rocks were more or less favorably exposed. But this was not always the case, for not infrequently mineralogical or paleontological terms were used for the names of the divisions. Much the same system prevailed during the period of the more active investigations of Dr. Orton and it is only during the last few years that the movement has arisen to place the nomenclature of stratigraphical geology on a basis similar to that of the biological sciences. Two of the most potent influences in this movement are the International Congress of Geologists and the United States Geological Survey. The most important principles of nomenclature governing the United States Survey are: first, a formation is a lithological unit representing the physical conditions of deposition, and should be called by the same name so far as it can be traced and identified by means of its lithologic characters aided by its stratigraphic associations and its contained fossils. The formation shall receive a distinctive designation, the preferred form being binomial of which the first member is geographic and the other lithologic. When the formation, however, consists of beds differing in lithologic character, so that no single lithologic term is applicable, the word "formation" shall be substituted for the lithologic term. The second principle is the rule of priority.[1] These two principles of nomenclature have been very imperfectly observed in most of our stratigraphical geology and as recently as December 1899, Dr. J. M. Clarke, state paleontologist of New York, and Mr. Charles Schuchert published a revised classification of the formations of New York in which a number of time-honored names were replaced by new terms.[2]

REVIEW OF FORMER CLASSIFICATIONS

In 1838 Professor C. Briggs, Jr., the fourth assistant geologist of the first geological survey of Ohio, proposed the name

[1] Tenth Ann. Rept. U. S. Geol. Surv., 1890, pp. 64, 65.

[2] Science, N. S., Vol. X, 1899, pp. 874–878.

"Waverly sandstone series" for the rocks occurring between the "argillaceous slaty rock, or shale stratum," now known as the Ohio shale, and the "conglomerate" which lies at the base of the Coal-measures. Waverly is the name of the capital of Pike county in southern Ohio and Professor Briggs stated that "As some of the most beautiful stones that have been obtained were quarried at Waverly, we may, for the present, denominate these rocks the Waverly sandstone series."[1]

In the following report, for some reason, Professor Briggs used the term "fine-grained sandstone" in place of the Waverly in his descriptions of the geology of Hocking, Athens, and Crawford counties.[2]

In the first report of the Newberry survey, Dr. Newberry and Professor Andrews revived the name, "Waverly sandstone."[3] Professor Andrews stated that it consisted of "A group of sandstones and shales, measuring on the Ohio River 640 feet in thickness (from the black slate to the base of the sub-Carboniferous limestone in the Kentucky hills), [which] rests conformably upon the black slate."[4] He further described a stratum of bituminous black shale 16 feet in thickness, 137 feet above the base of the group to which he gave the name "Waverly black slate."[5] It was also stated that between the Coal-measures and Waverly in Hocking county was "a group of comparatively fine-grained, buff-colored sandstone," 133½ feet in thickness which was named the Logan sandstone."[6] Below the Logan sandstone was given 85 feet of rocks which were stated to be composed of fine-grained sandstones alternating with conglomerates and this

[1] First Ann. Rept. Geol. Surv. Ohio, p. 80.

[2] Second Ann. Rept. Geol. Surv. Ohio, 1839, pp. 122, 130. See also his section of the strata of Ohio, facing p. 109. The same term was used by Mr. Foster, another assistant; see pp. 76 and 103, and, facing p. 73, his "Geological section along the National road from the Scioto River to the eastern line of Muskingum county."

[3] Geol. Surv. Surv. Ohio, Pt. I, Rept. Progress in 1869, 1870, p. 21; Pt. II, p. 65.

[4] *Ibid.*, Pt. II, p. 65. [5] *Ibid.*, p. 66.

[6] *Ibid.*, p. 76. The "section on Hocking River" on the "map showing the Lower Coal Measures" at the close of this report gave the thickness of the Logan sandstone group as 144 feet.

division in some parts of the report is called the "Waverly conglomerate."[1] Professor Andrews identified these two divisions in the Licking Valley and stated that "at Black Hand, near the east line of Licking county, the conglomerate is probably fifty or sixty feet thick, and over it lies, as we follow the dip to the southeast toward Zanesville, the Logan sandstone group. The Logan sandstone, with its characteristic fossils, is found to extend to a point between Pleasant Valley and Dillon's Falls, on the Baltimore and Ohio Railroad."[2]

Dr. Newberry stated that the Waverly group, as it was then called, "In the northern part of the state . . . . is much less homogeneous [than in the southern part], and is composed of the following elements:

	Feet
Cuyahoga shale (dove-colored shale and fine blue sandstone)	150
Berea grit (drab sandstone)	50
Bedford shale (red and blue clay shale)	60
Cleveland shale (black bituminous shale)[3]	20–60."

This classification was repeated by Dr. Newberry in 1873 in his report on the geology of Cuyahoga county, with a revision of the thickness of the several divisions, as follows:

		Feet
Waverly group	Cuyahoga shale	150–200
	Berea grit	60
	Bedford shale	75
	Cleveland shale[4]	21–60

At a later date the Cleveland black shale was referred by Dr. Orton and some other geologists to the Devonian system. The same classification for the Waverly was given by Dr. Newberry in 1874 under his description of the Carboniferous system.[5] In this volume Professor N. H. Winchell reported numerous outcrops of the Berea grit succeeded by the Cuyahoga shales and

[1] See p. 135 and explanation of the "section on Hocking River" on the "map showing the Lower Coal Measures."

[2] *Ibid.*, p. 79. Also see *ibid.*, Rept. Progress in 1870 [1871], p. 59.

[3] *Ibid.*, Pt. I, Rept. Progress in 1869, p. 21.

[4] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, p. 184. [5] *Ibid.*, Vol. II, Pt. I, p. 87.

sandstones in northern central Ohio in Crawford, Morrow, and Delaware counties.[1] This identification of Professor Winchell's is important because it carried correctly, for the first time, the Berea grit with the overlying Cuyahoga shale from northern Ohio to the central part of the state. Dr. Orton published the descriptions of the geology of Pike and Ross counties in this volume, and gave the following subdivisions of the Waverly series:

At the base are from 80 to 100 feet of the *Waverly shales*,[2] a name apparently proposed by him. This was followed by what he termed the *Waverly Quarry System*, with a thickness of 32½ feet, one mile south of Jasper.[3] Immediately above the sandstone is a black shale, from 16 to 27 feet in thickness, which, Dr. Orton stated, had been "designated by the chief geologist the '*Cleveland shale*' and by Professor Andrews the '*Waverly black slate*;'"[4] while the remaining part of the series, including everything "above the Waverly black slate and below the Carboniferous series" was denominated the Upper Waverly, composed of shales and sandstones with a maximum thickness not exceeding 425 feet.[5]

Meek in 1875, in giving the horizon of *Discina* (*Orbiculoidea*) *Newberryi* Hall, stated that certain specimens came "from the Berea shale, a member of the Waverly group of the Lower Carboniferous,"[6] which is, apparently, the first usage of the name in a stratigraphical sense, although it does not clearly appear that Meek intended to separate the shale from the subjacent Berea grit.

In 1878 Dr. Orton's "Report on the geology of Franklin county" was published, and in it occurs a description of the Waverly group as far as represented in the county. The Huron shale, the youngest formation of the Devonian system, was described as closing with "a red or chocolate-colored band, from

[1] *Ibid.*, pp. 240, 259, and 280.

[2] *Ibid.*, p. 619. [3] *Ibid.*, p. 621. [4] *Ibid.*, p. 624. [5] *Ibid.*, p. 649.

[6] Rept. Geol. Surv. Ohio, Vol. II, Pt. II, Palæontology, p. 278. See also statements in explanation of Plate XIV.

15 to 20 feet in thickness." Outcrops of these red shales were mentioned as occurring at "Taylor's Station, in Jefferson township, and at several points in Mifflin township, on the eastern bank of Big Walnut Creek. One exposure in particular may be named, which is very conspicuous, viz., the one seen in the slate cliff, opposite Central College." [1]

Dr. Orton's correlation of the divisions of the Waverly was as follows:

		Feet
Waverly group of the sub-Carboniferous period	Cleveland shale - - -	15
	Waverly quarry system -	60
	Waverly shales [2] - - -	10–20

In the report above mentioned Dr. Orton said "the Cleveland shale of Dr. Newberry, the Waverly black shale of Professor Andrews . . . . is known at but a single locality in the county, viz., at Ealy's Mills, in Jefferson township, on the banks of Rocky Fork. From 10 to 15 feet of this formation are here shown within the compass of an acre." [3] Dr. Orton further stated that Professor Winchell was in error in correlating the sandstone at Sunbury, Delaware county, with the Berea grit, his statement being as follows: "The Sunbury stone is erroneously referred in Vol. I [Vol. II] to a higher division of the Waverly, viz., the Berea grit, but it certainly belongs to the lowest of the sandstone courses of this formation." [4] The same volume contains the "Report on the Geology of Licking County," by M. C. Read, who described therein the upper Waverly of that county. The oldest division noted by Read was the *Waverly conglomerate*, which was said to be "conspicuously exposed along the south bank of the Licking in Madison and Hanover townships, presenting abrupt, precipitous bluffs 20 to 40 feet high." [5] The conglomerate was succeeded by the "olive shales," which were said to occupy "an interval of 150 to 190 feet below the Carboniferous conglomerate," [6] and were described as composed mainly of shales, but with some "strata of massive sandstone."

[1] Rept. Geol. Surv. Ohio, Vol. III, Pt. I, p. 638.

[2] *Ibid.*, p. 639.

[3] *Ibid.*, p. 642.

[4] *Ibid.*, p. 642.

[5] *Ibid.*, p. 360.

[6] *Ibid.*, p. 359.

In July 1878 Professor L. E. Hicks, of Denison University, announced "the discovery [of] an unmistakable outcrop of Cleveland shale [which] exists two miles east of Sunbury in Delaware county, southern [central] Ohio, on the land of Horace Whitney. It lies *above* the calcareous sandrock of the Sunbury quarries, which Professor N. H. Winchell, a special assistant of the Ohio geological survey, identified as *Berea grit.* My discovery *demonstrates* the incorrectness of that identification, and raises a strong presumption, amounting almost to a certainty, that he was equally wrong in respect to his Berea grit in Morrow and Crawford counties."[1] Professor Hicks made no reference to the classification of the Waverly and identification of the Cleveland shale in Franklin county by Dr. Orton, and on the other hand Dr. Orton did not mention Professor Hicks' papers in any of his publications so I am unable to state which article has priority. The September number of the same periodical contained a classification of the Waverly group in central Ohio by Professor Hicks, which was stated to include the rocks lying between the Huron shales and the base of the Coal-measures. The classification is as follows:

	Feet thick
5. Licking shales - - - - - - -	100–150
4. Black Hand conglomerate and Granville beds -	85–90
3. Raccoon shales - - - - - - -	300
2. Sunbury black slate - - - - -	10–15
1. Sunbury calciferous sandrock[2] - - -	90–100

The following year Dr. Orton published a "Note on the Lower Waverly Strata of Ohio" in which for the first time the Waverly black shale of southern Ohio was correctly correlated with the black shale directly above the Berea grit in northern Ohio for which the name Berea shale was proposed. This furnished the key for the correct correlation, between northern and southern Ohio, of the lower formations of the Waverly series, which was summarized in the following table:

[1] Am. Jour. Sci., and Arts, 3d ser., Vol. XVI, p. 71.

[2] *Ibid.*, p. 216.

Northern Ohio		Southern Ohio	
Cuyahoga shale - - Upper beds fossiliferous	150–250 ft.	Shale and sandstone - Upper beds fossiliferous	300–400 ft.
(Berea shale) - - - Included by Newberry with Cuyahoga	10 ft.	Waverly black shale - -	15 ft.
Berea grit - - - -	60 ft.	Waverly quarries and overlying blue shale - - - -	60 ft.
Bedford shale - - -	75 ft.	Waverly shale - - -	90 ft.
Cleveland shale		Great black shale [1]	

In 1888 Dr. Orton published a general classification of the Waverly group which he considered as composed of the Bedford shale, the Berea grit, the Berea shale, the Cuyahoga shale, and the Logan group. The Cuyahoga shale, however, was restricted to the shales and fine-grained sandstones between the Berea shale and the base of the conglomerate and sandstone forming the upper part of the Waverly. This upper division was called the Logan group which was said to consist of the Waverly conglomerate and Logan sandstone of Andrews as found in Hocking, Fairfield, and Licking counties. To the north the olive shales of Read in Knox and Richland counties were correlated with the Logan sandstone.[2] The same classification was republished by Dr. Orton in his last report for the Ohio survey.[3]

In 1888 Professor C. L. Herrick, who had studied the paleontology and stratigraphy of the Waverly series of central Ohio more thoroughly than any of the former observers, published his conclusions. Professor Herrick had also studied the Waverly of northern and southern Ohio and rocks of similar age in Pennsylvania and western New York, so that his classification was not intended to be confined to the rocks of central

[1] *Ibid.*, Vol. XVIII, p. 139.

[2] Rept. Geol. Surv., Ohio, Vol. VI, pp. 33–42.

[3] *Ibid.*, Vol. VII, 1893 [1895], pp. 26–35.

Ohio. The upper part of the series he correlated with the formations of the Mississippi valley and two quite persistent conglomerate horizons were named Conglomerate I and II.[1]

The classification is as follows:

Cuyahoga or Waverly series	Logan	Keokuk, 100–150 ft. Burlington
	(Conglomerate II)	
	Kinderhook, 50–60 ft.	
	(Conglomerate I)	
Berea or Transition series (*Western equivalent of Upper Chemung*)	Waverly shale, 40 ft.	
	Berea shale, 200–400 ft.	
	Berea grit, 50–60 ft.	
	Bedford shale, 50 ft.	
	Cleveland shale (local), 50 ft.	
Erie shale, Eastern or typical Chemung (lower part), 100 ft.[2]		

In the above classification the Berea shale included Dr. Orton's Berea shale and all of his overlying Cuyahoga shale except its fossiliferous upper 40 feet which, extending to the base of Conglomerate I, was called the Waverly shale.

In 1889 Dr. Newberry stated that the Waverly group "where best seen, as in northeastern Ohio, ... is about 500 feet thick, and fills the interval between the Erie shale (Chemung) below and the Carboniferous conglomerate above."[3] The following classification of the Waverly group was given:

	Average thickness feet
1. Cuyahoga shale	230
2. Berea shale	20
3. Berea grit	60
4. Bedford shale	75
5. Cleveland shale[4]	50

[1] Bull. Sci. Lab., Denison University, April 1888, Vol. III, p. 24; see also section on p. 26.

[2] *Ibid.*, December 1888, Vol. IV, pp. 105, 106. The zones of these formations with their characteristic fossils and thickness are given in detail on pp. 99–101.

[3] Mon. U. S. Geol. Surv., Vol. XVI. The Paleozoic Fishes of North America, p. 120.

[4] Loc. cit.

It will be noticed that Dr. Newberry accepted the separation of the Berea shale from the Cauyhoga shale ; but did not accept the reference of the Cleveland shale to the Ohio shale. This point he discussed quite fully and stated that the union of the Cleveland, Erie, and Huron shales to form the Ohio shale seemed unwarranted.[1] Dr. Newberry referred to Professor Hicks announcement of the discovery of the Cleveland shale in Delaware county, saying in conclusion: "I think he has found there the Berea shale, which lies immediately above the Berea grit."[2]

In 1891 Professor Herrick reviewed the general stratigraphy of the Waverly series, commencing with the Bedford shale. The lower boundary of the Waverly, however, he thought "must be found in the Berea grit, which . . . . is a sharply limited and easily recognizable horizon throughout Ohio."[3] The Berea grit came next, followed by the Berea shale, which, he states, is a term "conveniently applied to the thin band of bituminous shale above the grit, and perhaps should not be extended (as the writer has done in a previous paper) to the gray and blue shales above."[4] For the overlying rocks he used the name Cuyahoga shale in the sense in which it was used by Dr. Orton, except that the upper 40 feet, as in the previous paper, was called the Waverly shale. This division was stated to be stratigraphically continuous with the Cuyahoga shale which it also resembled lithologically, but paleontologically it more closely resembled the succeeding division or Kinderhook. The last division was called the Burlington and Keokuk.

REVISED CLASSIFICATION

This concludes the review of all the important papers published concerning the classification of the Waverly series of central Ohio. As a result of this study followed by an examination of the formations in the field, the writer proposes the following classification for the Waverly series of central Ohio.

[1] *Ibid.*, p. 128.

[2] *Ibid.*, p. 129.

[3] Bull. Geol. Soc. Amer., Vol. II, p. 35.

[4] *Ibid.*, p. 35.

No attempt is made, however, to correlate the formations with those of the sub-Carboniferous of other states:

	Feet
6. Logan formation (Andrews)	115
5. Black Hand formation (Hicks)	40–(120?)
4. Cuyahoga formation (Newberry)	275–300
3. Sunbury shale (Hicks)	10–15
2. Berea grit (Newberry)	40
1. Bedford shale (Newberry)	85+

Bedford shale was named by Newberry in 1870[1] from the outcrops at Bedford, southeast of Cleveland, at which place, he later states, the best exposure occurs.[2] The term "Bedford rock" appears in Richard Owen's description of the geology of Lawrence county, Indiana, published in 1862;[3] but it was not used as the name of a geological division. This interpretation is apparently confirmed in the subsection of the report devoted to the general description of the sub-Carboniferous limestone where the term "Middle or Lawrence—Crawford sub-Carboniferous limestone"[4] is proposed, a name evidently employed to denote a geological division. Mr. E. R. Cumings, of Indiana University, informs me that the Bedford oölitic limestone belongs in this division.[5] Writers since Owen have used the terms "Bedford stone," "Bedford oölitic stone," and other names for the rock, which was finally excellently described in 1896 by Hopkins and Siebenthal under the formation name of the "Bedford oölitic limestone."[6] It is the opinion of the writer, however, that the term "Bedford shale" used by Dr. Newberry as the name of a formation in 1870 is the one that should stand and the Indiana formation name of Bedford oölitic limestone should be dropped. Since the above was written Mr. E. R. Cumings has proposed the name, Salem limestone, for the Bedford oölitic limestone of Indiana.[7]

[1] Geol. Surv. Ohio, Pt. I, 1870, p. 21.

[2] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, 1873, p. 189.

[3] Rept. Geological Reconnoissance of Indiana during 1859 and 1860, p. 137.

[4] *Ibid.*, p. 125. [5] Letter, January 13, 1901.

[6] Twenty-first Ann. Rept. Ind., Dept. Geol. and Nat. Resources, pp. 291, 298.

[7] Am. Geol., Vol. XXVII, March 1901, p. 147.

This formation succeeds the Ohio shale, and as the Cleveland and Erie shales are supposed not to extend to central Ohio it probably rests on the Huron shale in Franklin county. The lower part of the formation in this county is well shown on the eastern bank of Big Walnut Creek east of Central College where the following section occurs :

	Thickness feet	Total thickness feet
No. 7. Till and soil - - - - - - -	5	87½
6. Fine green argillaceous shale. *Bedford shale*	7	82½
5. Mixed chocolate and greenish shale, mostly olive color - - - - - - -	7½	75½
4. Chocolate shale composed of fine clay -	21⅔	68
3. Fine green to olive argillaceous shales. Near base blocky shales containing fossils. *Base of Bedford* - - - - - -	17⅓	46⅓
2. Fine black shales containing small concretions. *Huron shale* - - - - - -	24½	29
1. Covered to level of Big Walnut Creek -	4½	4½

The greater part of the formation is shown on Rocky Fork, commencing about one and a half miles east of Gahanna and continuing up the creek for a mile. About one fourth mile up the creek from the ford on the north and south road is an outcrop, on the southern bank, of three feet of black shale which is nearly at the top of the Huron shale. A short distance farther up the creek is a higher bank which gives the following section :

	Thickness feet	Total thickness feet
No. 3. Till - - - - - - - - - -	6½	28¾
2. Fine chocolate shales of the Bedford - -	7	22⅓
1. *Bedford shales.* The upper part is somewhat sandy but the grains are very fine, and the lower part is composed of greenish to bluish argillaceous shale. Creek level - - -	15⅓	15⅓

At the second bluff to the west of the private bridge is the following section :

	Thickness feet	Total thickness feet
No. 2. Till - - - - - - - - - -	7⅔	36
1. Chocolate argillaceous shale which weathers to a red clay. *Bedford shale.* Creek level -	28⅓	28⅓

To the east of the bridge the base of the till is much lower than on the western side and there is a marked line of unconformity between the till and Bedford shale. Two hundred and twenty-five feet east of the above section is the following, which shows an irregular surface on which the till was deposited:

	Thickness feet	Total thickness feet
No. 2. Till with beds of sand - - - - - -	49⅓	54
1. Bedford chocolate shale. Creek level - - -	4⅔	4⅔

The covered interval between this bank and the next one is extensive enough to hide the top of the chocolate shale and the bluff is composed of grayish shales of the upper Bedford capped by the Berea sandstone. The following section is shown on the western bank of the creek below a tree:

	Thickness feet	Total thickness feet
No. 4. Till - - - - - - - - - - -	5	56½
3. Grayish sandstone layers about one foot thick. *Berea sandstone* - - - - - - - -	14	51½
2. Sandy, fine-grained shales with argillaceous ones above and below - - - - - -	9¾	37½
1. At the top a sandy concretionary layer 2 ± feet thick. Shales mostly grayish and argillaceous. In the lower part are spots of reddish-gray shale somewhat similar to the mottled shale No. 5 east of Central College. Level of creek	27¾	27¾

The Bedford shale includes the red band from 15 to 20 feet in thickness, which Dr. Orton, in his report on Franklin county, considered the upper part of the Huron shale;[1] the gray shale between the red and black Huron shales which was not mentioned in the county report; and the Waverly shales.[2]

2. *Berea grit* was named by Dr. Newberry in 1870, from the large quarries at Berea, southwest of Cleveland.[3] It is well shown on Rocky Fork, to the north of the outcrops of the Bedford shale and on the banks of Big Walnut Creek about one mile northeast of Sunbury, Delaware county. There are beautiful examples of ripple marks in the sandstone at both of these localities. On the eastern bank of Rocky Fork is an exposure of 31½

[1] *Ibid.*, Vol. III, Pt. I, p. 638. [2] *Ibid.*, p. 639. [3] Geol Surv. Ohio, Pt. I, p. 21.

feet of gray, thin bedded Berea sandstone, some of the layers a foot or more in thickness, with some partings of clay shale below which are 8 feet of bluish Bedford shales partly argillaceous and partly arenaceous, while in the upper part are thin layers of sandstone. The thickness of the Berea sandstone on this creek is about 40 feet and in the upper part at the highway is a small quarry. On the western bank of the Big Walnut between the railroad and highway bridges, one mile northeast of Sunbury, there is from 26 to 30 feet of it shown in the vertical cliff. This formation is called the "Waverly quarry system" in the report on Franklin county,[1] and the "Sunbury Calciferous sandrock" by Professor Hicks.[2]

3. *Sunbury shale* was named by Professor Hicks in 1878, from outcrops on Rattlesnake Creek on the present farm of Amos Whitney, about two miles east of Sunbury. North of the Whitney house there is an outcrop of 3½ feet of this black shale on the northern bank of the creek, and it may be seen at irregular intervals for some distance down the stream. A single specimen of a *Lingula* was the only fossil found, but the lower part of the shale is concealed and the top of the Berea grit crosses the creek a little below the house of Mr. W. P. Swallow. There is a much better exposure on Rocky Fork, in Franklin county, where the contact of the shale and Berea is shown just above the highway bridge on the David Meyers farm. The lower 2 feet of the very fossiliferous shale is exposed, containing abundant specimens of *Lingula melie* Hall, and *Orbiculoidea Newberryi* Hall, together with fragments of fish bones and teeth. Farther up the creek 8 + feet of the shale is shown on the western bank resting on the Berea grit.

This shale was first inappropriately named the "Waverly black slate" by Andrews in 1870[3] because the term Waverly had already been used for the larger division which includes this shale. Geological nomenclature is being revised for the purpose of eliminating and preventing the duplication of geographic

[1] *Ibid.*, Vol. III, p. 639. [2] Am. Jour. Sci., 3d ser., Vol. XVI, p. 216.

[3] Geol. Surv. Ohio, Pt. II, 1870, p. 66.

names of stratigraphic divisions of the same or different rank. The name Berea shale, proposed by Dr. Orton in 1879,[1] is excluded, first, by the law of priority, since Sunbury shale was published and defined by Professor Hicks the preceding year, and second, because Berea had been used in 1870 by Dr. Newberry for the name of a formation. The division termed the Cleveland shales in the report on Franklin county is the Sunbury shale.[2]

4. *Cuyahoga formation* (shale) was the name given by Dr. Newberry in 1870[3] to "the uppermost member of the Waverly group" and was described as crossing Cuyahoga county and forming the banks of the Cuyahoga River to the Cuyahoga Falls.[4] Originally the Sunbury shale constituted the lower part of this formation, and in 1888 Dr. Orton separated the coarser deposits of conglomerate and sandstone in the upper part of the Waverly, as found in central and southern Ohio, from this formation, under the name of the Logan group,[5] and said this "upper member of the series [Waverly] is wanting in the Cuyahoga Valley, or is at least very inadequately represented there."[6]

Professor Herrick in 1891 from paleontological and stratigraphical evidence showed that this upper part of the Waverly is wanting in northern Ohio, and said: "We can positively assert that the Cuyahoga shale as represented in the northern tier of counties is identical with that part of the Waverly lying below Conglomerate I . . . . of central Ohio. The fossiliferous horizons of Granville, Newark, Rushville, and Winchell's Division 4, on the Ohio River, are all above the top of the Cuyahoga."[7]

Finally, Professor Herrick stated in 1893 that in the "northern localities the calcareous, concretionary layer, which has yielded so abundant a fauna in central Ohio, was discovered at

[1] Am. Jour. Sci., 3d ser., Vol. XVIII, p. 138.

[2] Loc. cit., pp. 639, 642.

[3] Geol. Surv. Ohio, Pt. I, p. 21.

[4] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, p. 185.

[5] *Ibid.*, pp. 37, 39.

[6] *Ibid.*, p. 39.

[7] Bull. Geol. Soc. America, Vol. II, p. 37. See also the section of Cuyahoga Valley and Bedford, on p. 40, where it is stated that "This entire series [upper part of the Waverly] is absent in the northern tier of counties to the base of Conglomerate I."

a distance of 40 feet beneath the Coal Measure conglomerate and most of the characteristic species re-collected. This served to settle the question conclusively except for the few feet above this horizon."[1]

The present writer considers the Cuyahoga shales of central Ohio as composed of the shales and sandstones occurring between the top of the black Sunbury shale and the base of the coarse deposit called by Professor Herrick Conglomerate I. In this formation, therefore, is included the 40 feet of fossiliferous shales immediately underlying Conglomerate I of Professor Herrick which he called the Waverly shale.[2] Should a separation of this shale from the Cuyahoga prove necessary it would require a different name, because Waverly had already been used—first, as the name of a series; second as the name of the conglomerate in central and southern Ohio; third, as the name of the black shale in southern Ohio; fourth, as the name of the sandstone in the vicinity of Waverly; and fifth, the identical term Waverly shale by Dr. Orton for the lowest division of the series in southern Ohio.[3]

This formation was called the Raccoon shales by Professor Hicks, who said: "It appears in force all along Raccoon Creek and its tributaries, and extends westward into Franklin and Delaware counties."[4] Its thickness was estimated by Professor Hicks as 300 feet, while Professor Herrick stated that "the Cuyahoga proper is never more than 200 feet thick."[5]

In central Ohio the Cuyahoga formation is composed largely of bluish to grayish shales and buff sandstones which are fairly well exposed on Moot's Run and other streams in the western and central parts of Licking county.

[1] Rept. Geol. Surv. Ohio, Vol. VII, 1893, pp. 502, 503.

[2] Bull. Denison Univ., Vol. IV, 1888, p. 107.

[3] Rept. Geol. Surv., Ohio, Vol. II, Pt. I, 1874, pp. 619, 648; and Figs. 1 and 2 of the report on Pike county.

[4] Am. Jour. Sci., 3d ser., Vol. XVI, 1878, p. 219.

[5] Bull. Geol. Soc. Amer., Vol. II, 1891, p. 38.

5. *Black Hand formation* (conglomerate) is the name given by Professor Hicks in 1878 to the deposits of coarse sandstone and conglomerate exposed at Black Hand in the gorge of the Licking River and about Hanover.[1] Both of these localities are in Hanover township, in the eastern part of Licking county. We find, as in the case of most conglomerates, that when this formation is followed for some distance there are quite decided differences in the lithologic character of the rocks. In the vicinity of Newark and Granville they are mainly sandstones, with some layers of shales and two comparatively thin strata of conglomerates. Professor Hicks states that these beds are well exposed at Granville and are only a local modification of the Black Hand conglomerate, and for convenience he designated them "the Granville beds."[2] Professor Andrews in 1870 called this division the Waverly conglomerate;[3] but this name was preoccupied, because Waverly had already been used for the name of the series. He correlated the conglomerate at Black Hand with that of the Waverly and gave its thickness at that locality as probably 50 or 60 feet.[4]

At Havens' quarries, on the farm of Mr. G. W. Havens, one and one half miles southeast of the central part of Newark, is a good exposure of the sandstone phase of this formation. The section begins in the conglomerate stratum on the bank of Quarry Creek below the quarries, where an excavation has been made in prospecting for gold, and continues to the top of the bank above the quarry on the eastern side of the run. The quarry on the western side of the creek is shown in Fig. 1, the lower part of which is in the Black Hand and the upper the Logan formation.

[1] Amer. Jour. Sci., 3d ser., Vol. XVI, pp. 216, 217.

[2] *Ibid.*, p. 218.

[3] Geol. Surv. Ohio, Pt. II, p. 135, and on the explanation of the "Section on Hocking River" of the "Map showing the Lower Coal Measures."

[4] *Ibid.*, p. 79.

FIG. 1.—Havens quarry on the western bank of the stream. The lower part shows the massive sandstone of the Black Hand formation, the top of which is Herrick's Conglomerate II, indicated by the two upper students. Succeeding Conglomerate II the lower part of the Logan formation is shown.

SECTION AT HAVENS' QUARRY

	Thickness feet	Total thickness feet
No. 9. Till and soil	2	75
8. Alternating shales and sandstone	14½	73
7. Massive buff sandstone splitting into many layers	16	58½
6. Bluish argillaceous shales	4½	42½
5. Conglomerate stratum No. II of Herrick; average thickness 11 inches	1	38
4. Bluish fossiliferous shales containing numerous specimens of *Spirophyton* and other fossils; was called the "Allorisma layer" by Herrick	6½	37
3. Grit containing a few fossils	½	30½
2. Light gray to buff fine-grained sandstone, which is called freestone and quarried. This forms a massive zone which splits into several layers. The upper 8 feet of this zone is shown in this quarry, and, at the base in the gold-mine opening, nearly 3 feet of drab argillaceous shale, below which is 3¼ feet of coarse-grained buff sandstone. In the Havens quarry, on the western side of the creek, nearly 20 feet of this sandstone is shown, and in the Vogelmeier quarry, one and one half miles south of Newark, 27 feet of sandstone, separated by a 5-inch bluish shaly layer 9 feet below the top. In certain layers of this sandstone fossils are common, especially *Syringothyris cuspidatus* (Martin).		
1. Conglomerate stratum, 3 feet thick. Sandstone parting, 7 inches. Massive conglomerate with quite large pebbles, which are coarser than in the upper layer. Level of creek (Conglomerate No. I of Herrick)	5	5

From the freestone No. II of the above section the following species were collected:

1. *Syringothyris cuspidatus* (Martin) (c).
2. *Spirifer Winchelli* Herrick.
3. *Crenipecten Winchelli* (Meek) (c).
4. *Platyceras Hertzeri* Winch (r).
5. *Chonetes pulchella* Winch (rr).
6. *Rhipidomella* (*Orthis*), cf. *Michelina* L'Eveillé (c).

7. *Cryptonella eudora* Hall (rr).
8. *Camarotœchia marshallensis* (A. Winch) ? (rr)

The Allorisma shales No. IV contain the following species:

1. *Allorisma ventricosa* Meek (rr).
2. *Sanguinolites* (?) *obliquus* Meek (r).
3. *Sanguinolites œolus* Meek (r).
4. *Sanguinolites* sp.
5. *Camarotœchia marshallensis* (Win.) (?) or *C. Cooperi* Shum. (?)
6. *Allorisma Winchelli* Meek (c).
7. *Sanguinolites naiadiformis* Winch. (r).
8. *Prothyris Meeki* (Winch) (r).
9. *Spirophyton* cf. *crassum* Hall (c).
10. *Syringothyris cuspidatus* (Martin) (rr).
11. *Liopteria* sp. (rr).
12. *Discina* (*Orbiculoidea*) *pleurites* (Meek) (?) (rr).

Professor Andrews did not definitely indicate the boundaries of the Waverly conglomerate; neither did Professor Hicks those of the Black Hand conglomerate and Granville beds. The thickness of the conglomerate near Hanover was given as from 85 to 90 feet,[1] and that of the Granville beds as from probably 25 to 111 feet.[2]

The Fucoid layer (No. 4c) of Hicks' Granville beds is the same as the "Allorisma layer" of Professor Herrick's and No. 4 of the Havens section. Division No. 2 of Professor Herrick's, which he called the Middle Waverly or Kinderhook, was clearly defined by Conglomerate No. I at the base and Conglomerate No. II at the top,[3] and by its fossils correlated with the Kinderhook formation of the Mississippi valley. This formation is apparently quite well marked by these two conglomerate strata in the vicinity of Newark, and Professor Herrick identified Conglomerate II in sections from Ashland county to Sciotoville on the Ohio River,[4] and later states that the Allorisma shale is "very persistent and well limited, even when the Conglomerate (No.

[1] Am. Jour. Sci., 3d ser., Vol. XVI, p. 217.

[2] *Ibid.*, p. 218. The statement is not clear, and 85 feet possibly represents the minimum thickness.

[3] Bull. Denison Univ., Vol. IV, 1888, pp. 105, 106.

[4] *Ibid.* See sections on p. 102.

VOGELMEIER QUARRY, NEWARK, OHIO.

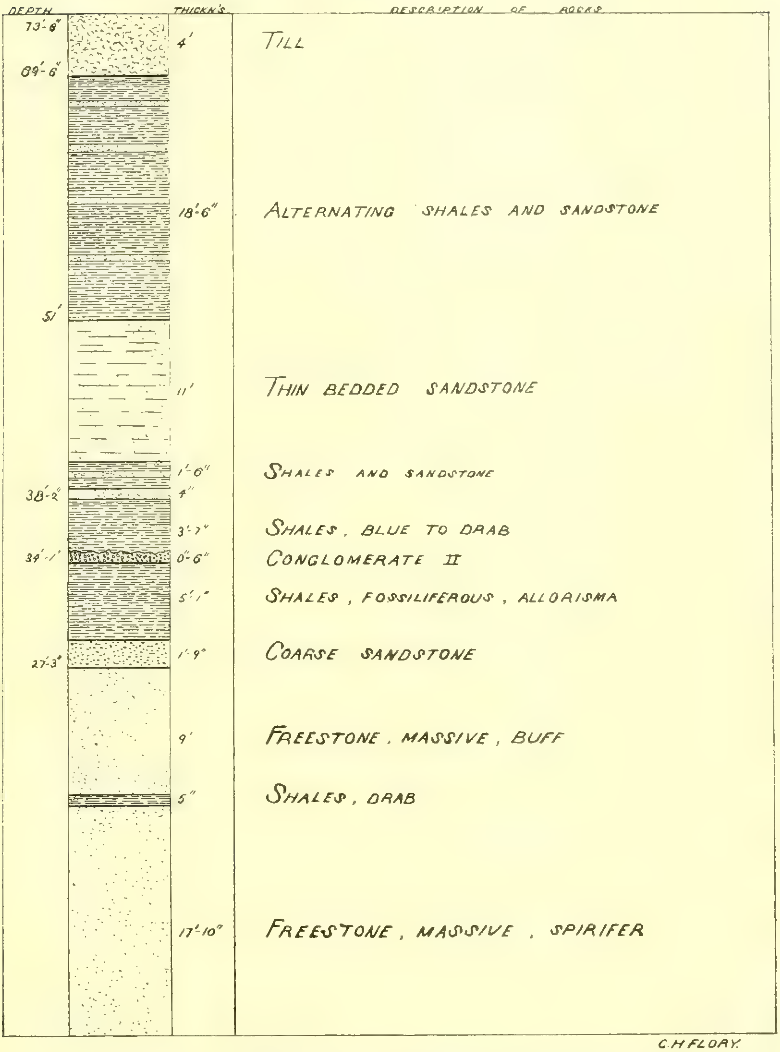

FIG. 2.—Section of Vogelmeier quarry, southeast of Newark, showing a part of the Black Hand and Logan formations. Conglomerate II is considered the line of division between them.

II) is absent, having been traced from Sciotoville to the northern exposures in Wayne county."[1] Conglomerate No. I seems less persistent than No. II, but below the freestone there are generally thick shales, so that the base of the formation is quite distinct stratigraphically.

In the vicinity of Hanover and in the gorge of the Licking River at Black Hand are excellent exposures of the conglomerate phase of the formation. Below Hanover, on the western

FIG. 3.—Ledge of Black Hand conglomerate below Hanover.

side of Rocky Fork, is a fine cliff of the conglomerate 80 feet high, which is shown in Fig. 3, while apparently its top, as shown by partial exposures in the field above the brow of the cliff, is some 35 feet higher. Professor Hicks gave the thickness of the Black Hand conglomerate at Hanover as from 85 to 90 feet,[2] and Professor Herrick reported that in the region about Clay Lick station, in Hanover township, "is a great development of the conglomeratic phase of the Waverly. One half mile east of Clay Lick there is a nearly continuous exposure of about 100 feet of alternating conglomerate and coarse sandstone of prevailingly red color."[3]

[1] Bull. Geol. Soc. America, Vol. II, 1891, p. 38.

[2] Am. Jour. Sci., 3d ser., Vol. XVI, 1878, p. 217.

[3] Bull. Sci. Lab. Denison Univ., Vol. II, 1887, p, 15.

To the east of the Hanover railroad station is a cut in which the contact of the Black Hand conglomerate and overlying Logan sandstone is nicely shown. To the south of the cut and highway is the quarry of the Hanover Pressed Brick Co. in the shales of the Logan formation. The section from the railroad to the top of the quarry is as follows:

	Thickness feet	Total thickness feet
No. 4. Mainly blue to drab argillaceous shales with some bands of sandstones which vary from 7 inches to perhaps a foot in thickness -	20	92
3. Covered - - - - - - - -	18	72
2. Buff shaly thin bedded sandstones containing fossils which are well shown in the upper part of the railroad cut in the vicinity of the highway bridge. Lower part of the *Logan sandstone* which is separated by quite a sharp line from the massive grit to conglomerate below. There are some thin layers of conglomerate near the base of the Logan sandstone.	22	54
1. Massive grit to conglomerate which forms the lower portion of the cut. Part of the rock is a buff grit and the remainder a conglomerate some of the pebbles of which are quite large.	32	32

BLACK HAND CONGLOMERATE

The Black Hand conglomerate named from the cliffs in the gorge of the Licking River, known as the Licking Narrows, begins a short distance above the station of Black Hand on the Baltimore and Ohio Railroad.[1] On the north side of the river rather more than a quarter of a mile above the bridge are two conspicuous cliffs, the lower one called Red Rock and the upper one Black Hand which is shown in Fig. 4. On the southern side of the river is a railroad cut which shows finely the contact of the Black Hand conglomerate and the Logan sandstone. To the west of the cut at a distance of about one half mile from the station is a prominent cliff in one part of which is the E. H.

[1] For a description of the topography of this region and the former as well as the present gorge of Licking River, see Professor W. G. Tight's paper in Bull. Sci. Lab., Denison Univ., Vol. VIII, Pt. II, pp. 36–43, and Pls. I, II.

Evertts & Co. quarry for glass sand. The following section was measured at this locality from the level of Licking River to the top of the cliff.

SECTION OF SOUTHERN BANK OF LICKING RIVER AT EVERTTS & CO. QUARRY

	Thickness feet	Total thickness feet
No. 6. Till - - - - - - - - - -	7	101
5. Thin, irregular bedded, drab or bluish sandstone and bluish argillaceous shales. In places at the bottom is a 3-inch clay shale resting on the massive conglomerate with a sandstone to conglomerate layer above. Lower part of the *Logan sandstone* - -	22	94
4. A coarse conglomerate stratum at the top of the conglomerate which in places is 11 inches thick. The top of the *Black Hand conglomerate* - - - - - - - - -	1	72
3. Gray to drab coarse grit, which in places is a conglomerate that is worked for glass sand. This forms the upper part of the main cliff -	21	71
2. Coarse grit and conglomerate to the base of the cliff at the Crusher - - - - -	16	50
1. Mostly covered bank below the Crusher but all in the conglomerate as shown by exposures a little farther down the river. Level of Licking River - - - - - - -	34	34

6. *Logan formation* (sandstone) was named by Professor Andrews in 1870 from outcrops in Hocking county near Logan,[1] and was stated to overlie the conglomerate at Black Hand and to extend down the Licking Valley "to a point between Pleasant Valley and Dillons Falls."[2] This division was named the Licking shales by Professor Hicks, who states that they are well developed in the hills bordering Licking River from Newark to Black Hand, 100 to 150 feet in thickness, and "lie 70 to 80 feet above the water level, forming the middle of the slope of these hills, the base being composed of the massive Black Hand conglomerate and the upper slopes and summit of the various strata of the Coal

[1] Geol. Surv. Ohio, Part II, pp. 76, 79. [2] *Ibid.*, p. 79.

Measures."[1] This formation is Division 3, or the Upper Waverly of Professor Herrick, which he gave as 80 feet in thickness in Licking county and which, from the fossils, he correlated with the Burlington and Keokuk of the Mississippi valley.[2]

In 1888 Dr. Orton united the Waverly conglomerate and Logan sandstone of Andrews to form the Logan group.[3] If it

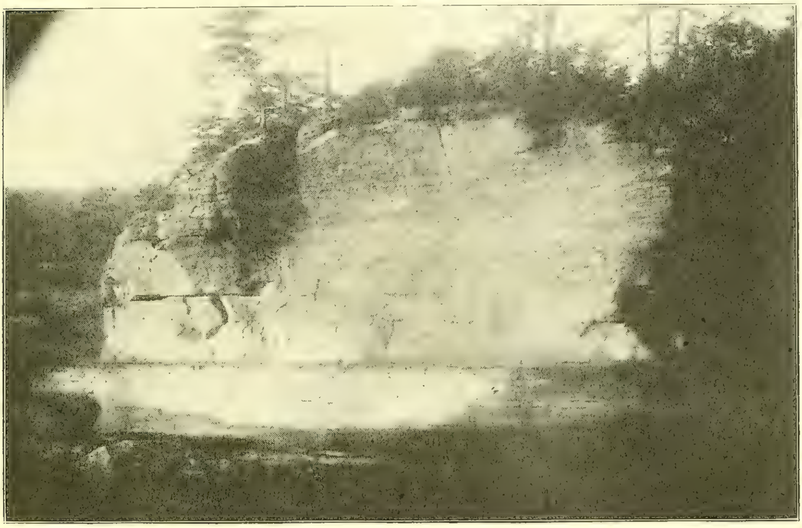

FIG. 4—Black Hand rock in the gorge of Licking River.

be advisable to make one formation of these two divisions, the above name is inappropriate because the Logan sandstone of Professor Andrews clearly referred to the upper division only, as has been noted by Professor Herrick.[4]

The above ruling is believed to represent the position of the United States Geological Survey, as shown by the following quotation from a recent letter of Mr. Bailey Willis, assistant in

[1] Am. Jour. Sci., 3d ser., Vol. XVI, 1878, p. 216.

[2] Bull. Denison Univ., Vol. IV, 1888, pp, 99, 100.

[3] Rept. Geol. Surv., Ohio, Vol. VI, p. 39.

[4] Bull. Geol. Soc. Amer., Vol. II, 1891, p. 38.

geology to the Director of the United States Survey and Geologist in charge of Areal Geology, to whom these questions in nomenclature are referred:

The survey distinctly recognizes the right of priority, that is to say, the name first applied to a well defined geologic unit is to be preferred. The qualifying conditions, on account of which the name may be rejected and one of later application used, are (1) that the name has been previously applied to some other unit, and (2) that the unit to which the name was applied was not well defined.

Thus, in the case which you cite, the term Waverly conglomerate (Andrews) would not hold if Waverly had previously been used for something else, and by application of the same rule Waverly series should be discarded if Waverly conglomerate had priority. The Logan group (Orton) should not stand as opposed to Logan sandstone.

In these questions there is often a personal element which makes it a matter of regret that some desirable name should not be adopted, but we feel that the advantages of clearness and definition in science must be superior to such conditions, and that the rule should be rigidly applied.[1]

Dr. George H. Girty, of the United States Geological Survey, who has been engaged for several years in a thorough study of the stratigraphy and paleontology of the Waverly series in Ohio, Michigan, and Pennsylvania, concurs in regarding the upper part of the series in central Ohio as composed of two formations, as may be seen from the following quotation:

I have seen the Logan group at Logan and vicinity and also at various points in Licking county. I quite concur with you in regard to the separateness of the two component members in central Ohio at least, and am in uncertainty as to the reasons which led Professor Orton to unite the two beds under a common name.[2]

The lower part of this formation is well shown in the Vogelmeier and Havens quarries, where Conglomorate II is succeeded by from 4½ to 6 feet of greenish-gray to bluish argillaceous shales, and these are followed by from 11 to 17 feet of quite massive buff sandstones, capped by alternating shales and sandstones, 18½ feet of which are shown at the top of the Vogelmeier quarry. There are fair exposures of the remaining part of the formation in "the gorge" to the east of the Havens quarry,

[1] Letter of December 18, 1900. [2] Letter of January 5, 1901.

partly in the bank of the creek and partly by the roadside, where 85 feet of buff arenaceous shales to thin bedded sandstones are shown. This gives about 115 feet for the thickness of the formation, which is capped by the Coal-measure conglomerate where the road and creek emerge from the woods. In sections farther to the south and southeast the top of the Logan sandstone is defined by the base of the sub-Carboniferous limestone, named by Professor Andrews the Maxville limestone.

CHARLES S. PROSSER.

COLUMBUS, OHIO,
December, 1900.

THE USE OF BEDFORD AS A FORMATIONAL NAME

In a paper about to be published by Professor Charles S. Prosser it will be stated that the "*Bedford shale* was named by Newberry in 1870[1] from outcrops east of Cleveland at which place, he later states, the best exposures occur." It will be further stated that the term "Bedford rock" as used by Owen[2] for a portion of the Sub-Carboniferous limestone of Indiana was evidently not intended as a formation name.

In the citation of Owen's use of the term Bedford rock lies the basis for the present use of the name Bedford for the Indiana formation. In the later reports of the Indiana Geological Survey, down to the Twenty-first Annual Report, the name Bedford is not applied to these rocks; but in the Fifteenth Annual Report the name Salem rock[3] is used, though not as a formation name, and again in the Seventeenth Report, Salem is said to afford the "best exposure for study [of the oölitic limestone] from the geologist's point of view."[4] In the Fifteenth Report (*loc. cit.*) a section of the Salem Stone and Lime Company's quarry one half mile west of Salem is given as follows:

Soil and rubbish - - - - - - - -	3 feet
Dark blue, bituminous limestone (bastard) -	6 "
Gray oölitic quarry stone - - - - - -	30 "
Blue crystalline limestone - - - -	6 "
Total - - - - - - - - -	45 feet

The oölitic character of the rock is said to be especially well shown in this section.

Since the term Bedford as the name of a formation is preoccupied, having been applied to the "Bedford shale" of

[1] Geol. Surv. Ohio, Part I, Rept. Progress in 1869, 1870, p. 21.

[2] Geol. Recon. Indiana, 1862, p. 137.

[3] Ind. Geol. and Nat. Hist., Fifteenth Ann. Rept., p. 143.

[4] Indiana, Dept. of Geol. and Nat. Resources, Seventeenth Ann. Rept., p. 47.

northeastern Ohio in 1870, the writer proposes the name *Salem limestone* for the rocks called Bedford limestone by Hopkins and Siebenthal.[1] The so-called bastard limestone of the quarrymen is to be considered as the base of the formation next above (Mitchell); and the base of the Salem formation is to be taken at the top of the Bryozoal limestone that throughout its entire extent constitutes the upper zone of the Harrodsburg limestone as defined by Hopkins and Siebenthal.[2]

In suggesting a different name for the rocks under consideration the writer is aware of the claims of Spergen hill. The latter place is, however, chiefly known as having afforded the extensive series of fossils described by Hall[3] and later redescribed and figured by Whitfield,[4] and is not so good a place for studying the stratigraphic relationships of the formation as a number of other localities. Moreover, the Spergen hill fauna is confined to parts of the formation, and in many localities would be of scarcely any service in identifying it. The oölitic character of the rock, on the other hand, while more pronounced at some places than at others, everywhere serves as a means of identification and is the character that is especially well developed at Salem. Finally, as indicated above, the name Salem has been associated with the oölitic limestones in the Indiana reports since 1885.

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[1] Indiana, Dept. of Geol. and Nat. Resources, Twenty-first Ann. Rept., 1896, p. 298.

[2] *Ibid.*

[3] Trans. Alb. Inst., Vol. IV; Indiana, Dept. Geol. and Nat. Hist., Twelfth Ann. Rept.

[4] Bull. Am. Mus. Nat. Hist., Vol. I, No. 3.

ON THE USE OF THE TERM BEDFORD LIMESTONE

It has not been the custom of the Indiana geologists to give local geographic names to geologic formations, and previous to the twentieth report of the state geologist (for 1895) but three or four formations had been so described. The earlier geologists were content to correlate the rocks with the formations of adjoining states and use the names already in use.

The business of quarrying the oölitic limestone grew up at a number of points. The quarry rock was recognized to be equivalent but was not known to be continuous. It was thought to exist in "deposits." Each locality was jealous of the qualities of its "deposits." So we had *White River stone*, *Elletsville stone*, *Bedford stone*, *Salem stone*, etc. In the course of time the greater development of the quarries at Bedford caused that stone to dominate the others in the market, and the Indiana oölitic limestone came to be generally known as *Bedford stone*, and as such, it has been specified by architects in more than thirty states. Its reputation having become thus established, all localities were willing to have their stone known as *Bedford stone*, and geologists were no longer embarrassed by local rivalry in giving this name to the formation.

Dr. R. T. Brown, state geologist, in a "Geological Survey of the State of Indiana," published in 1854,[1] gives a section of the rocks at the railway cut near Harristown (presumably that celebrated later as Spergen Hill), recognizing the quarry ledge with its characteristic fossils to be equivalent to that quarried at Bedford, and the same as that shipped from the northwestern part of Monroe county as *White River stone*.

Richard Owen[2] in 1862 used the term *Bedford rock*, referring to stone quarried from the formation in question at Bedford. It

[1] Transactions of the Indiana State Agricultural Society, 1853, pp. 311, 312.

Geological Reconnoissance of Indiana, 1862, p. 137.

may be noted here that in the Bedford region the formation is practically homogeneous and is quarried from top to bottom.

The reports of the Indiana Survey for 1869, 1870, and 1872 deal exclusively with the coal deposits. The report for 1873 mentions *Bedford stone* on pages 276, 280, 282–284, and 312. The report for 1874 does not touch upon the formation. The report for 1875 alludes to the oölitic limestone of Owen county as *white quarry stone.* In the report for 1878 an analysis of stone from Bedford is referred to in the index as *Bedford stone.*

The reports from 1880 to 1895 inclusive speak of this stone as Indiana oölitic limestone, though that from Bedford is called Bedford stone (1881, p. 31), and, as mentioned in the preceding article, that from Salem is called *Salem stone* (1885–6, pp. 143–146). So, too, it had been called *Salem stone* in the preceding report (1884, pp. 76–78).

In the report by T. C. Hopkins and the writer (1896, pp. 289–427) the oölitic limestone of the different quarries was for the first time shown to be not only equivalent but actually continuous. A single name became imperative. It was at hand. The name *Bedford oölitic limestone* was adopted rather than proposed as a new name. To have proposed a name would have raised the question of priority, and *White River limestone* would clearly have been entitled to precedence. Under the title *Bedford stone* this limestone was as well known as a geologic formation can be, over more than half the United States. The term which had been originally applied to the whole formation at one place was now extended to the formation throughout its extent.

We think that these facts justify the prior claims of Indiana to Bedford as a formation name, and that it will not be necessary to drop the term. But drop it we could not if we would, for, to the trade, *Bedford stone* it will be to the end of the chapter.

C. E. Siebenthal.

NITRATES IN CAVE EARTHS

A NEW theory of the origin of nitrates in cave earths has been recently propounded by Mr. William H. Hess (JOUR. GEOL., Vol. VII, p. 2) who considers that they are the product of the nitrifying bacteria in the soil above, and that they enter the cave with the seepage through the roof and are deposited by the total evaporation of the water in the dryer parts of the cave. In other words the dry galleries and chambers of a cave serve as a gigantic natural still, catching the seepage from the surface and retaining the solids. Inasmuch as the older theory that these nitrates are leached from the bat guanos formed in the caves is on the face of it sufficient to account for the facts while difficulties arise in the application of the new theory a comparison would seem to be in order. The first and most serious objection Mr. Hess urges against the older theory is a statement that bats never go far from the mouth of the cave, while many analyses (not quoted) show that the nitrates are distributed through the dry chambers of the cave. This would seem to be decisive if rigorously verified, for if bats never went far from the entrance it would be exceedingly difficult to account for the presence of derivatives of bat guano in all dry portions of the cave. In reality, bats frequent in very large numbers remote portions of caves. Dr. O. C. Farrington, in a recent expedition through the caves of Indiana, found bats in all parts of the caves visited.[1] Mr. Hess' second objection is that the cave earth contains little or no organic matter. Two specimens in the collections of the Field Columbian Museum, one from Indiana and one from South America do contain organic matter visible on casual inspection. As the niter, according to the general opinion, is for the most part not a decomposed or altered guano but a residual clay or sand impregnated with soluble salts by seepage from bat guano, there is no reason why it should

[1] Field Columbian Museum Publication 53, p. 244.

contain insoluble organic matter or more organic matter than is indicated by the amount of nitrogen and chlorine shown by Mr. Hess' analyses. This objection, apparently based on inspection of the specimens and a single analysis, cannot therefore be considered proven. The third objection made by Mr. Hess to the origin of nitrates in the cavern itself is that while the cave earth and the bat guano contain approximately equal quantities of phosphates, the soluble phosphate is much less in the underlying earth than in the overlying guano. This, however, is merely an illustration of a phenomenon with which all phosphate manufacturers are familiar, viz., the "reversion" of the soluble to the insoluble phosphate by virtue of which a very large percentage of the "available" or soluble acid calcium phosphate of a "superphosphate" when applied to the soil, changes to various insoluble phosphates.[1] It does not appear, then, that any of the above objections are in any sense conclusive.

In support of the external origin of the nitrates, Mr. Hess calls attention to the fact that the leachings from the surface subsoil contain nitrates in small quantity. He also attempts to show by analyses that the soluble portions of the niter earth might be the concentration of the leachings from surface soils, although the figures he gives appear to prove the reverse. Inasmuch as both the niter earth and the surface soil are both (in the Kentucky and Indiana caves) residual soils from limestone, contaminated with organic matter, a general similarity in consequence of similarity of origin is to be expected and is found. But if the soluble salts of the niter earths are the soluble salts transported from the overlying soil, more than a general resemblance should appear. After due allowance is made for compounds which will not redissolve the two should be practically identical if the analyses correctly represent the average constitution of the mixtures in question. As printed, Mr. Hess' analyses do not admit of ready comparison. If the analysis which he gives (p. 131) of subsoil over Mammoth Cave and of the cave earth directly below are recalculated so as

[1] WYATT: Phosphates of America.

to indicate the percentage composition of the soluble portion (on the assumption that the analyses are complete) they compare as follows:

SALTS LEACHED FROM SUBSOIL AND FROM CAVE EARTH, MAMMOTH CAVE

	Na_2O+K_2O	CaO	SO_3	P_2O_5	N_2O_5	NH_4
1. Subsoil.........	15.32	9.58	28.72	tr.	36.17	10.21
2. Cave earth......	28.94	20.54	42.10	0.003	8.30	00.001

The resemblance is purely qualitative, and it is very evident that the second substance could not be formed by the evaporation of a solution of the first as the theory requires. The water which enters the cave forms stalactites and stalagmites and, therefore, must carry carbonate of lime. In the aqueous extract from the subsoil, considered below, the bases are saturated with nitric and sulphuric acid and hence it contains no carbonates. This analysis therefore does not represent the waters which enter the cave. It is most probable that these waters after leaving the subsoil take up carbonate of lime and other material while passing through the rock roof and enter the cave with the composition of the drip water whose analysis is given by Mr. Hess (*loc. cit.*, p. 132).

From the analysis of waters dripping into Mammoth Cave made by Mr. Hess, the figures below have been derived calculating the ratio of certain salts for comparison with the soluble salts from the cave earths of Mammoth and Saltpeter Caves, also recalculated from Mr. Hess' analyses.

SALTS LEACHED FROM CAVE EARTH COMPARED WITH CORRESPONDING SALTS FROM DRIP WATER

	K_2O+Na_2O	CaO	SO_3	P_2O_5	Cl	N_2O_5	NH_4
Certain salts from drip water, Mammoth Cave...........	23.24	42.37	22.18	tr.	3.83	8.06	0.06
Cave earth, Mammoth Cave..	27.23	19.91	40.56	......	5.26	6.95	0.09
" " " "	22.39	23.56	33.65	......	10.38	10.01	0.007
" " Saltpeter Cave...	22.62	23.13	33.03	......	2.30	18.82	0.07

From this table it is evident that solids from the drip water contain practically twice as much lime as those from the cave earth and much less sulphates and chlorides. Exact calculations for the saturation of bases by alkalies cannot be made without knowing the ratio of soda to potash. An inspection of similar determinations for many Kentucky soils shows for similar situations a ratio of potash to soda of 1 : 4. Assuming this ratio, then, in the case of the drip water, after all the acids are saturated there is a large excess of lime left. This holds true both for the salts given in the above table and for the full analysis as given by Mr. Hess. This lime is held as carbonate and would be deposited as calcite upon evaporation. But in the salts extracted from the cave earths, as before noted, we find that the acids nearly saturate the bases and there is little lime left as carbonate. While the quantities will change as we assume more or less soda in the mixed alkalies, yet the proportions do not vary to any important degree, and in any conceivable case there is a very large excess of calcite in the drip water unaccounted for in the cave earth. In short, the drip in Mammoth Cave carries chiefly carbonates, while the cave earths carry chiefly sulphates. For the drip water to deposit any nitrate it is necessary that it should evaporate practically to dryness and deposit essentially all of its lime and other salts. For every 8 parts of nitric acid, 42 parts of lime will be deposited, and thus the deposit would take the form of stalagmite enclosing the clay or sand, a form of deposit actually found in places but not forming any portion of the cave earth.

The removal of nitrates from guano to cave earth is different. The drip becomes saturated with salts while passing through the guano, deposits only part of its burden in the underlying cave earth, and drains off with the remainder. The deposits thus formed will be composed chiefly of the more soluble instead of the less soluble salts, and no stalagmite will form. This may be made more evident by assuming an ideal case. Take 1 liter of water saturated with calcium nitrate, calcium carbonate, and carbonic acid at 54° F. Keeping the temperature constant, let

the water evaporate until only ¾ liter remains. One liter of water at 54° F. will hold in solution approximately 1100 grams of calcium nitrate[1] and (disregarding the influence of the calcium nitrate) only 0.88 gram of calcium carbonate.[2] When reduced to ¾ liter by evaporation it will hold only 825 grams of calcium nitrate and 0.66 gram of calcium carbonate. If the solution be now removed, there remains a precipitate of 275 grams of calcium nitrate and only 0.22 gram of calcium carbonate. This applies to all cases of soluble with slightly soluble salts except where chemical actions intervene, as in the case of phosphates. In one specimen from Dixon's Cave the analysis of the cave earth, recalculated below, shows a very large excess of carbonates. In this case the amount of soluble salts is very minute (0.5655 per cent.), and we probably have the beginning of a stalagmite deposit forming in the nitrates. Over 90 per cent. are bases, with only 5½ per cent. of sulphuric acid. There is no analysis of dropping waters for comparison in this case, however.

SALTS LEACHED FROM CAVE EARTH AND OVERLYING BAT GUANO, DIXON'S CAVE.

	$NaO_2+{}_2KO$	CaO	SO_3	P_2O_5	Cl	N_2O_5	NH_4
1. Bat guano, Dixon's Cave.....	3.50	31.68	6.35	0.42	—	57.08	0.97
2. Cave earth underlying 1	45.98	40.67	5.48	2.42	—	2.09	3.36

As the overlying bat guano in this case yields up to water salts of which over 57 per cent. are nitric acid, it is difficult to understand how a water carrying the traces of nitrates from the surface of the earth could penetrate this guano to the underlying cave soil without taking along much more nitric acid from the bat guano than the almost infinitesimal quantities it brings from the surface. In this case the soluble part of the deposit is undoubtedly a mixture of the matter in the drip and the matter leached from the bat guano, and there is a bare possibility that

[1] OSTWALD: Outlines of Theoretical Chemistry, p. 150.

[2] ROSCOE and SCHORLEMMER: Treatise on Chemistry, Vol. II, Pt. I, p. 209.

a very small quantity of nitrate from the surface may be mixed with the much larger quantity leached from the bat guano above.

There are, however, better indicators than the carbonate or sulphate of lime. These are chlorine and the phosphates. The chlorine has not been given in a sufficient number of Mr. Hess' analyses to be available in this discussion, but the data regarding the phosphates are more complete. Inasmuch as phosphates "revert" or become insoluble, the total phosphate, not the soluble, must be considered. Mr. Hess finds only traces of phosphate in the drip or in the soluble extract from the soils of the surface, while the quantity of phosphoric acid in the guano and the niter earth is approximately equal and is very considerable, 2.62 per cent. and 2.10 per cent. respectively. While the approximation to equivalence is doubtless accidental, yet it is undeniable that there is in cave earth much more phosphate in proportion to the niter, alkalies, etc., than the drip water could bring in. An abundance of phosphate is found in soluble form in the bat guano. Mr. Hess regards this excess of phosphate as a concentration in the residual soil, of the calcium phosphate of the limestone on account of its insolubility. But it appears from the figures given by Penrose and others[1] that the percentage of phosphate of lime in limestone and in its residual clay is approximately the same, the larger part of the phosphate going into solution with the carbonate of lime. Penrose selected clay from a hollow in the limestone where it was overlain by 15 feet of similar clay and a chert cap, and compared it with the limestone. He found phosphoric acid in the limestone 3.02 per cent. and in the clay 2.53 per cent. It is not contended that under exceptional circumstances phosphates may not be concentrated as a residuum after solution of limestone, as Safford claims for those of Tennessee, but it is contended that such concentration, if it occur at all, is very unusual, and furthermore that it does not occur in the cave regions of Kentucky and Indiana.

Although no determinations of phosphoric acid in limestone and its residual soil can be found for the immediate vicinity of

[1] MERRILL: Rocks, Rock Weathering, and Soils, p. 232.

Mammoth and the other caves considered, yet the above conclusion may be confirmed for the State of Kentucky by the following figures from the analyses of rock and soil made for the Kentucky Geological Survey.[1]

No.	Substance.	P_2O_5, per cent.
570.	Subsoil	0.440
571.	Red underclay	0.425
572.	Limestone	0.221
573.	Limestone	0.196
576.	Subsoil, Bourbon county	0.243
577.	Underclay	0.221
578.	Limestone	0.093
579.	Limestone	0.183
614.	Subsoil	0.316
615.	Limestone	0.311
663.	Virgin soil, Jessamine county	0.239
664.	Virgin soil, Jessamine county	0.666
666.	Limestone	0.567
683.	Subsoil	0.459
684.	Underclay	0.456
685.	Limestone	0.631

In preparing the above table all cultivated soils have been excluded, and it is believed that only examples of virgin soils, subsoils and underlying limestones that are properly comparable have been included. The average of these figures is 0.315 per cent. P_2O_5 for the limestones and 0.365 per cent. P_2O_5 for the soils. The average of twenty-five analyses of subsoils overlying limestone in Kentucky is 0.264 per cent. P_2O_5. Mr. Hess finds 2.62 per cent. P_2O_5 in bat guano and 2.10 per cent. P_2O_5 in cave earth. This is obviously a far greater proportion of phosphate than is found in other residual clays, and as in the drip water he finds only a trace of phosphate with 53.61 milligrams carbonate of lime, the difference can hardly be made up from that source. On the other hand, the bat guano provides an abundant supply, as all the phosphorus used in the metabolic processes of bat life must eventually find its way to the guano. Finally, it

[1] Third Report Geol. Surv. Kentucky.

may be noted that Mr. Hess' claim that nitrates are uniformly distributed in the dry chambers of caves is not substantiated by the analyses of cave earths of Wyandotte Cave made for the Indiana Geological Survey.[1] Besides the analysis of niter earth, there is given one of the magnesian earth which is abundant in the dry portions of Wyandotte Cave. The analysis of this earth shows no nitrates. An interesting variation between the distribution of nitrates and of other nitrogen compounds throws much light upon the problem, and has been investigated by Müntz and Maracano for some Venezuelan caves.[2] "There is thus a gradual change in the character of the nitrogenous combination from the interior to the exterior portions of the cave, as shown in the following analyses:

Constituents	Guano from interior of cave	Earth from entrance	Earth some distance from entrance
Organic nitrogen	11.74 per cent.	2.41 per cent.	0.80 per cent.
Nitrate of lime	0.00 "	3.03 "	10.36 " "

If the transformation of organic nitrogen through ammonia and nitrites to nitrates by the action of bacteria occurs only at the surface, there should be no uniform variation in the proportions of these components in the cave earths, but such a variation as has been found might occur from the mouth of the cave inward if the bacteria are acting in the cave itself. Mr. Hess has doubtless performed a service in pointing out a method by which cavern deposits of nitrates may be formed, and it is not improbable that such deposits may be discovered. Deposits thus formed, however, will have several easily recognized features not found in the cavern earths now known.

HENRY W. NICHOLS.

FIELD COLUMBIAN MUSEUM,
March 2, 1901.

[1] Indiana Geol. Surv., 1878, p. 162.

[2] MERRILL: Rocks, Rock Weathering, and Soils, p. 372.

DERIVATION OF THE TERRESTRIAL SPHEROID FROM THE RHOMBIC DODECAHEDRON

Two papers have recently been published which tend to again awaken special interest in the theme of the grand plan of the earth. One is the presidential address of Professor B. K. Emerson on the "Tetrahedral Earth and the Zone of the Intercontinental Seas," delivered before the Geological Society of America; and the other is a lecture before the Royal Geographical Society by Dr. J. W. Gregory, on the "Plan of the Earth and Its Causes."

Both papers are an explanation and discussion of the quaint and suggestive conception of the tetrahedral form of the earth as advanced by William Lothian Green, an English merchant of Honolulu, an original thinker of no mean astuteness, who, in his *Vestiges of the Molten Globe*,[1] presents a hypothesis which can be, by no unbiased student, regarded as lying entirely within the fanciful.

Briefly stated, Green's hypothesis is that on the theory of a cooling globe, a noticeably angular or ridged form would result. As the sphere is the solid which contains the maximum volume under a given surface, so the geometrical form having the minimum volume under the same surface is the tetrahedron. Hence, the contracting globe would tend to assume the tetrahedral shape, as one permitting the greatest reduction of bulk with the least amount of change of surface.

Green takes as his fundamental form the hexatetrahedron with curved faces, as most nearly approaching the sphere. In the development of the hemihedral form of the hexatetrahedron the original faces retained give rise to one set of obtusely pointed pyramids; and the extended portions of the faces a second set of pyramids having more acute apices. The former represent the water areas of the globe and the latter the land

[1] Vestiges of the Molten Globe, Pt. I, London, 1875; Pt. II, Honolulu, 1887.

areas. There are then three triangles of water with their bases against a land triangle around the south pole, pointed northward and interlocked with three great southward-pointing land triangles, having their bases against the north polar triangle of water. Thus is explained the plan of the earth as indicated by its grandest geographic features.

The idea of a tetrahedral earth did not first originate with Green, though it was doubtless original with him. Neither is the attempt to reduce the earth to a faceted body unusual. From the time of Élie de Beaumont, more or less intense interest has been taken in the subject.

The distinctly tetrahedral conception has been, as Professor Emerson has noted, discussed by a number of writers. Richard Owen,[1] of New Harmony, Indiana, and brother of Dr. David Dale Owen, compared the form of the earth to the crystal of diamond. Besides Green, already mentioned, Michel-Lévy[2] has lately formulated his tetrahedral idea of the earth. Still more recently Gregory[3] has considered the subject much along the same lines as the writer last mentioned.

In comparing Green s tetrahedron with that projected by Michel-Lévy it may be noted that the obtuse pyramids of the former correspond very nearly to the sharp pyramids of the latter.

Now, the main object of the present note is to call attention to the fact that in all of these more recent attempts to reduce the earth to regular geometrical form there is an important suggestion that appears to have escaped notice. This is embodied in a short paper which appeared in the *American Meteorological Journal* for 1888,[4] under the title of the "Probable Derivation of the Terrestrial Spheroid from the Rhombic Dodecahedron." It is by the same Richard Owen who earlier gave expression to many of the facts and fancies connected with the idea of the tetrahedral earth.

[1] Key to the Geology of the Globe, p. 60, 1857.

[2] Bull. Géol. Soc. France, T. XXVI, p. 105, 1898.

[3] Geographical Journal, Vol. XIII, p. 225, 1899.

[4] Am. Meteorological Jour., Vol. V, p. 289, 1888.

The polar axis of the earth is regarded by Owen as extending from the center of one rhombic face to the center of the opposite one. The sharp, four-sided axial angles of the dodecahedron are near the Aleutian Islands, New Zealand, and, on the earth's equator, at Sumatra and Quito; while the remaining two lie in the Alps and south of the Cape of Good Hope. Thus oriented the following propositions are formulated:

1. Centers of rhombs are usually occupied by water or low land;

2. Ridges of rhombs usually give rise to mountains, and river sources; also sometimes to parallel valleys with important rivers;

3. Many of the apices are characterized by vicinity of volcanic groups;

4. Rhombs facing each other have considerable similarity in the distribution of land and water;

5. Daily rotation and annual revolution seem to have determined the configuration of land.

How closely these generalizations accord with facts may be easily tested by reference to any school globe. Why Owen should have oriented the dodecahedron just as he did does not appear. It would seem that in all cases of this kind the starting point which is first selected has much to do with subsequent developments. In Owen's case the depression of the Arctic Ocean offered the schematic rhomb. Then, too, the Mediterranean area required special attention. So important is the last named region that Michel-Lévy, in his plan, was led to make it a point where three polar edges of his tetrahedron should meet.

If there be anything in the idea of a collapsing crust on a shrinking interior, the tendency of the surface toward the assumption of any angular form would find adequate reason in an adjustment which would produce as nearly as possible the least amount of deformation in the lithosphere compared with the amount of change in the bulk of the earth. This geometrical shape is, as already noted, the tetrahedron; but a four-sided figure in which

each face would be of the most general form—that is, with six facets—curved after the manner of the diamond.

But while the natural tendency, in a collapsing shell, may be to assume a form affording the least change of the surface, extraneous conditions might impose slight modifications in other directions. The resultant form might then be a closely similar shape, having the same symmetry. As related to the hexatetrahedron, the rhombic dodecahedron is one of these forms. And Owen's scheme may more nearly correspond with observed facts than any plan based upon the strictly tetrahedral conception.

In any case, we should expect to have the great world ridges follow approximately the geometrical edges of whatever form is selected. In the central portions of the faces we should expect to find, on the whole, marked depressions. If these features are to be regarded as essential criteria, then Owen's scheme appears to offer fewer objections than any yet suggested. In these considerations the hydrosphere may be practically neglected.

The rhombic dodecahedron is a schematic form to which the great features of the earth are capable of even more exact adjustment than that proposed by Owen. If the dodecahedron be oriented so that one of its axes coincides with the earth's axis of rotation, the ends of the other two axes may be made to intersect the earth's equator where the latter passes through Sumatra, the west coast of Africa, the west shore-line of South America, and the Phœnix Islands, in the central Pacific Ocean. There will then be grouped around the north pole of the earth four rhombic faces as follows:

1. North American,
2. European,
3. Asian,
4. Bering.

Around the equator are:

5. Northern Pacific,
6. Atlantic,
7. Indian,
8. Eastern Pacific.

About the south pole are arranged:

9. South American,
10. South African,
11. South Indian,
12. South Pacific.

The great Cordilleran ridges of North America, from near the extremity of South America to the Arctic Ocean lie directly on the edges of the dodecahedral form. The line is marked by a remarkable succession of volcanoes both active and only recently extinct. Greenland lies on another of the polar edges of the northern zone of rhombs. Another remarkable world-ridge passes down on rhombic margins from Franz Joseph land, through Novaya Zemlya, the Urals, the Himalayas, Sumatra and the Sunda Islands, Australia to Tasmania. Between the last named place and the south pole is Wilkes Land and Victoria Land, with the active volcano Erebus near the line.

From Sumatra, northeastward extends the most wonderful line of active volcanoes known on the globe — the line bordering the east coast of Asia. From Japan a north polar edge is continued in the long island of Saghalien, certain chains of northeastern Siberia, and farther north in the Arctic Ocean by the Liakov Islands.

Other mountain ridges and groups of active volcanoes characterize most of the other edges of the dodecahedron, frequently in a very notable way.

The only apparently incongruous element in the scheme is Europe. But this comparatively high land has its antipodal representative rhomb in the deepest south Pacific.

However fanciful the speculations of this kind may be regarded, it is certain that mountain ranges are susceptible of systematic arrangement. Moreover, mountain ranges must be considered as having different taxonomic ranks according to their genetic origin.

We know that the smaller folds of the earth's strata are complex, that little ones may ride, as it were, on larger ones, and that these again may rise out of still greater swells. Structural

mountains may be thus likened to the waves of a tempestuous sea, and, within each province of the mightiest rolls, may be arranged in harmony with their taxonomic relationships.

The master earth ridges may have one origin, and be arrayed —not in sharply defined geometric figures, perhaps—but in accord with definable laws. Within the grand provinces defined by these greatest features, mountain ranges may be determined by wholly different causes—possibly in out-flowing, curved elevations, something after the manner suggested by Suess for Siberia. Parts of these systems may again be modified by still more local causes—being intensified in some places, softened in others.

In the consideration of mountains, as features of the earth's face susceptible of giving expression to its deepest emotions, we have to recognize fully, before we can hope to understand the riddle of their existence, that all do not possess the same taxonomic values.

CHARLES R. KEYES.

DES MOINES, IOWA.

THE VARIATIONS OF GLACIERS. VI.[1]

THE following is a summary of the Fifth Annual Report of the International Committee on Glaciers:[2]

RECORD OF GLACIERS FOR 1899

Swiss Alps.—As we approach the end of the century the advance of a number of glaciers which began in 1875 has gradually died out. Only one glacier was known to be advancing in 1899; nine were doubtful, and fifty-five were certainly or probably retreating.[3]

Eastern Alps.—During 1899 Drs. Blumcke and Hess published an important paper on the Hintereis glacier containing observations of the movement, melting, and interior temperature of the glacier, and an excellent map.[4] During the time of observation, in the summer, the temperature to a depth of forty meters was found to be practically the melting temperature.

The Vernagt glacier continues to advance; during the last year its velocity at a certain point has increased from 178^m per year to 280. Since it has been under observation (1889–1899) its velocity has increased to fifteen times its original value. The ice has thickened and the glacier is advancing.[5]

Of the glaciers observed in the Eastern Alps, fifteen are

[1] The earlier reports appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp. 378–383; Vol. VI, pp. 473–476; Vol. VII, pp. 217–225, and Vol. VIII, pp. 154–159.

[2] Archives des Sciences Phys. et Nat., Vol. X, pp. 1–20. Geneva 1900.

[3] Report of PROFESSOR FOREL.

[4] Untersuchungen am Hintereisferner. Wissensch. Ergans. z. Zeit. des D. u. O. Alpenvereins. 1. Bd. 2. Heft.

[5] A very complete account of this glacier was given by PROFESSOR S. FINSTERWALDER in the Wissensch. Erganzunghefte zur Zeits. des D. u. O. A–V. 1. Band, 1. Heft, Graz 1897. This important paper contains a history of the remarkable variations the glacier has suffered, and an excellent discussion of the nature of the movement of the ice and the origin of moraines.

advancing, thirteen are stationary, and more than twenty-two are retreating.[1]

Italian Alps.—Eight glaciers show a retreat and two an advance.[2]

French Alps.—The Société des Touristes du Dauphiné has recently published an important book on the glaciers of Dauphiné.[3] The conclusions are as follows :

As a rule the glaciers of this region have been in retreat during the second half of the nineteenth century, but some became stationary and a few even advanced between 1889 and 1893. Of the glaciers under observation twenty-four are in retreat and two are stationary. One of these, the glacier Blanc, is remarkable; it advanced before 1865, was in retreat from 1865 to 1886, and then began an advance which has continued until 1899; during this period the glaciers nearby were in retreat, though a few of them showed an advance for a short time. Three glaciers at present show a thickening which may result in an advance.

Swedish Alps.—The Mika glacier has been stationary since 1897. Observations have shown a velocity of 18.3^{cm} a day in summer, whereas the mean for the year is 7.6^{cm}.[4]

Norwegian Alps.—A number of glaciers have been under observation and show in general a very slight retreat. The western glaciers of Jotunheim advanced during the summer of 1898. During the last few years a small snowfall and much heat is reported for this region and these glaciers are again in retreat.[5]

Greenland.—Photographs of the small Kiagtut glacier, near Julianehaab, show a retreat of several hundred meters between 1876 and 1899. A small glacier on the island of Disko retreated 46^{m} between 1890 and 1891.[6]

[1] Report of PROFESSOR FINSTERWALDER. [2] Report of Mr. OLINTO MARINELLI.

[3] Observations sur les Variations des Glaciers et l'Enneigement dans les Alpes dauphinoises; edited by Professor W. Kilian. Grenoble, 1900.

[4] Report of DR. SVENONIUS.

[5] Report of DR. OYEN. [6] Report of DR. STEENSTRUP.

Canada.—The Victoria glacier, near Lake Louise, Alberta, is retreating though no measures have been made.

Photographs of the Asulkan glacier, British Columbia, show no changes between 1898 and 1899. A small glacier on the southern side of Mt. Sir Donald has become smaller.

The Illecellewaet glacier has been observed with more or less regularity since 1887, during this time it has apparently retreated on the average 15.8^{m} a year. There are indications that it was stationary or advancing before 1887. It retreated 4.9^{m} between 1898 and 1899. In August 1899 the velocity of the ice close to the end was 13.7^{cm} a day; 460^{m} further back and near the middle of the breadth it was 17.2^{cm}. The upper part of the glacier seems to be growing thicker.[1]

Russian Asia.—The report gives the locations of a number of glaciers, many of which show undoubted signs of retreat.[2]

Himalaya.—Mr. Freshfield has induced the government officials to undertake regular observations of some glaciers. He found the glaciers of Kindjinjanga advancing slightly after having suffered an insignificant retreat. In general there are no indications of any important changes among those glaciers in recent years.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1900[3]

The small glaciers in Montana continue to retreat.

A small glacier has been discovered on Mt. Arapahoe in

[1] Report of MESSRS. G. and W. S. VAUX, JR. See papers by the same authors: Some observations on the Illecellewaet and Asulkan Glaciers of British Columbia. Proc. Phil. Acad. of Nat. Sci., 1899, pp. 121–124.

Additional Observations on Glaciers of British Columbia. Proc. Phil. Acad. Nat. Sci., 1899, pp. 501–511.

The Glacier of the Illecellewaet. Appalachia, 1900, Vol. IX, pp. 156–165.

ALBRECHT PENCK, translated by D. R. Keys: The Illecellewaet Glacier in the Selkirks. Proc. Canadian Inst. 1900, pp. 57–60.

[2] Report of MR. MOUSCHETOFF.

[3] A synopsis of this report will appear in the Sixth Annual Report of the International Committee. The report on the glaciers of the United States for 1899 was given in this JOURNAL, Vol. VIII, pp. 154–159.

Colorado.[1] The only other glacier known in this state is the Hallett.[2]

The Eliot glacier on Mt. Hood, Washington, is retreating and growing thinner (*H. D. Langille*). This means that the retreat will probably continue for some years and at an increasing rate.

On September 3, 1899, an earthquake shook the Alaskan coast and caused a large quantity of ice to be broken from the ends of tide-water glaciers. Glacier bay was so full of ice during the summer of 1900 that the steamers which usually visit that region were unable to approach Muir glacier nearer than four or five miles, and no satisfactory estimates could be made of the retreat of the glacier.

The Windom glacier, which ends on gravel-deposits in Taku inlet, is reported to have suffered the loss of a large part of its end, due apparently to the washing out of the supporting gravels.

Miles glacier, near the Copper River, Alaska, shows a marked recession since last year (*A. C. Spencer*).

The United States Geological Survey has published a large volume on "Explorations in Alaska in 1898.[3] Several parties were sent to explore various routes from the coast to the interior and, although no especial attention was given to the study of the glaciers, sufficient observations were made to bring out some interesting facts; many glaciers are cursorily described and their locations shown on the maps. The Alaskan glaciers are all of the valley or Piedmont types; Alaska was never under a great ice sheet like the eastern part of North America. The glaciers in the mountainous regions to the north, east, and southeast of Cook's Inlet, many of which are very large, were formerly much more extensive than now, and show evidences of continued

[1] The Glacier of Mt. Arapahoe, Colorado, WILLIS T. LEE: This JOURNAL, Vol. VIII, pp. 647–654.

[2] F. H. CHAPIN: Appalachia, Vol. V. p. 1; and Mountaineering in Colorado, p. 97.

[3] Twentieth Ann. Rept. U. S. Geol. Surv., Part VII. See also ABERCROMBIE: The Copper River Exploring Exped. Washington, 1899.

retreat. Whereas the glaciers to the west and southwest of Cook's Inlet are small and, though retreating, they were never much larger than at present (*Spurr*, *Mendenhall*, *Eldridge*).

Professor I. C. Russell has published an account of the former and present glaciation in northern Washington.[1] A synopsis of the existing glaciers in this region was given in an earlier report of this series.[2]

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GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
March 15, 1901.

[1] I. C. RUSSELL: A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington. Twentieth Ann. Rept. U. S. Geol. Surv., Part II.

[2] This JOURNAL, Vol. IV, pp. 222–224.

PRODROMITES, A NEW AMMONITE GENUS FROM THE LOWER CARBONIFEROUS

CONTENTS

Occurrence of Paleozoic Ammonites.—Until twenty-five years ago it was thought that the ammonites were confined entirely to the Mesozoic, and that the Paleozoic representatives of the Ammonitoid group were all goniatites. This was in keeping with the theory that ammonites all belonged to a single stock or phylum. But the discovery in the Salt Range Permian of several genera of different stocks that could not, by any stretching of the name, be called goniatites, upset this idea. For a long time after this the Permian ammonite fauna of India was looked upon as exceptional until the recognition of the Permian age of the ammonite fauna of the Artinsk beds of Russia. This was followed shortly by the discovery of similar forms in strata of the same age in Sicily and in Texas. It was then universally recognized that these forms were not exceptional, and might be looked for wherever the uppermost Paleozoic was found in its marine facies. But even as late as 1891 we find the Permian ammonite species of Texas described as Mesozoic types occurring in Paleozoic beds, and in all text-books even today the Permian epoch is given as the period of transition from goniatites into ammonites.

Steinmann and von Sutner[1] were the first to attempt to divide the ammonites into various phyla, derived from separate stocks of goniatites, and while their classification is not always in agreement with the most rational arrangement, it is very suggestive,

[1] STEINMANN: Elemente der Palaeontologie, 1890.

and has caused much fruitful discussion. The main points for which they contended have been accepted, and now it is generally admitted that ammonite genera may be much more closely related to goniatites than they are to contemporaneous or even antecedent ammonites. Karpinsky's[1] masterly researches in the phylogeny of the Prolecanitidæ contributed largely to this result, and prepared the way for Haug's[2] exhaustive study of the relations of the various phyla of goniatites.

When it is once admitted that there are several distinct stocks of different degrees of specialization and developing in different directions, there is no longer any sound reason for the commonly accepted opinion that they all made the transition at the same time; indeed, it is extremely illogical to expect that this would be the case. In spite of this, it will cause surprise, especially among those that cling to time-honored criteria, when it is announced that not only are characteristic ammonites found below the Permian, but even at the very base of the Carboniferous system, and in such an advanced stage of development that the transition from goniatite to ammonite must have taken place already in the Devonian. The occurrence of these forms is authentic, and not sporadic, for they were found in the same horizon, and in the same faunal association in three widely separated localities in America. It may be that they were prematurely specialized forms, like *Clymenia*, that developed suddenly from the main, unspecialized stock, and as suddenly became extinguished; but the existence of similar and evidently closely related forms in the Trias presupposes continuance of the stock. In reality, our knowledge of the various families of Paleozoic animals is as yet only fragmentary, and lack of record is no very strong argument against the occurrence of any group. We must remember that the greater part of the Paleozoic deposits are not now open to our inspection, and that whole faunal provinces and

[1] Die Ammoneen der Artinsk-Stufe. Mém. Acad. Impér. Sci. St. Petersburg, seventh series, Tome XXXVII, No. 2, 1889.

[2] Études sur les Goniatites. Mém Soc. Géol. France, Paléontol., Tome VII, No. 18, 1898.

regions are now obliterated, either washed away entirely, or covered by the sea, or concealed by later deposits. The first records in the rocks or in text-books do not, by any means, agree with the first appearance of any group in geologic history. This is clearly seen when one notes the constant pushing back of the records of the first appearance of types, that has taken place in the past ten years. Our ideas of the specialization of organic life in Cambrian and even pre-Cambrian time have had to undergo radical changes as the discoveries of new faunas have followed fast upon each other.

Genus, **Prodromites**, *gen. nov.*, Smith and Weller.

Type, *P.* (*Goniatites*) *gorbyi* Miller, 1891, Advance Sheets Seventeenth An. Rep. Geol. Survey of Indiana, p. 90, Plate XV, Fig. 1 ; and Seventeenth An. Rep. Geol. Survey of Indiana, 1892, p. 700, Plate XV, Fig. 1.

The type species was originally described as a goniatite, but a most liberal interpretation of that group could not include this form, which was assigned to that division simply because of its occurrence in Carboniferous rocks.

The genus *Prodromites*[1] is characterized by its laterally compressed, discordal, involute, deeply-embracing whorls, narrow umbilicus, high, hollow abdominal keel, and complex, ceratitic septa. Where the keel is broken off, as is usually the case, the abdomen is narrow, slightly flattened, and angular. The surface, so far as known, is smooth, and destitute of ribs, constrictions, or other ornamentation. The septation is the most distinctive feature of this genus, on account of the large number of serrated lobes, and an extensive auxiliary series of lobes and saddles. The ventral lobe is rather long and undivided, the saddles all rounded and entire, the first four or five lateral lobes are serrated, and in addition to these there is a series of several pointed and more or less irregular auxiliary lobes.

The only Paleozoic form to which *Prodromites* may be likened is *Beloceras*, which it resembles only in its compressed involute form and the multiplication of the elements of the septa. The resemblance is not great, but the agreement is fundamental, and these two genera may safely be placed in the same family or phylum. A much greater resemblance and probably kinship connects this form with *Hedenstroemia* Waagen, of the Lower Trias of the oriental region. The best known species of that genus is *H. mojsisovicsi* Diener, Pal. Indica, *Cephalopoda of the Lower Trias*, page 63, Plate XX,

[1] The etymology of the word is from the Greek of scout or forerunner.

Figs. 1 *a–c*. In *Hedenstroemia*, as defined by Waagen,[1] the ventral lobe is divided, the external saddle divided by adventitious lobes; the first four lateral lobes are serrated, and there is a series of about six pointed auxiliary lobes. The form is flattened, involute with narrow and angular abdomen. No keel is known, and the shell is smooth. In *Prodromites* the ventral lobe is undivided and the external saddle is entire and rounded; but in the serration of the first four or five lateral lobes and in the auxiliary series it is almost identical with *Hedenstroemia*, as also in the form, with the exception of the keel, which may not have been preserved on the few specimens known. There can be no doubt that these two genera belong to the same family, and even subfamily, in spite of the long time that intervened between the Kinderhook formation of the Lower Carboniferous and the Lower Trias. *Hedenstroemia*, according to Waagen,[1] belongs to the Pinacoceratidæ, subfamily Hedenstroeminæ, which also contains *Clypites* Waagen, and *Carnites* Mojsisovics, of the Lower Trias. The family Pinacoceratidæ in the broader sense, as defined by Waagen (*op cit.*, p. 139), contain all forms with compressed involute whorls, many lateral lobes and saddles, and an auxiliary series of lobes outside of the umbilicus. In this family belong the following subfamilies: (1) Medlicottinæ, (2) Beloceratinæ, (3) Beneckeinæ, (4) Hedenstroeminae; all of which have representatives in American Paleozoic or Triassic strata.

It is not likely that *Prodromites* is a descendant of *Beloceras*, since the septation is quite different in the two genera; and unless *Hedenstroemia* should be found to have a keel, it is not likely that it has descended from *Prodromites*. *Beloceras* is commonly placed under the Prolecanitidae, although it antedates any typical species of *Prolecanites*. On the other hand, *Medlicottia*, which is closely related to *Prodromites*, seems certainly to have been a descendant of the typical Prolecanitidæ. No solution of these questions is possible until the ontogeny of several of these genera is known, which is prevented at present by a scarcity of specimens. Until other evidence is forthcoming, *Prodromites* is placed in the family Pinacoceratidæ, subfamily Hedenstroeminæ.

This genus is not founded solely on Miller's figure, which is not accurate, nor even on his type specimen, but also on three other specimens of this species, and one of another species, bringing out certain characters that did not show on Miller's type.

The writers have had at their disposal for study four specimens of *Prodromites gorbyi* Miller, and one of *P. praematurus* S. and W., all of which, except one, belong to the paleontological collection of the Walker

[1]Pal. Indica. Salt Range Fossils. Fossils from the Ceratite Formation, p. 140.

[1] Pal. Indica. Salt Range Fossils, Vol. II. Fossils from the Ceratite Formation, p. 140.

Museum at the University of Chicago, to the authorities of which the writers' thanks are due for the use of the specimens. The first specimen,[1] No. 6208, is Miller's type of *Goniatites gorbyi*, and came from the Chouteau limestone at Pin Hook Bridge, Pettis county, Missouri. A second specimen, No. 6474, was secured from Professor G. C. Broadhead. It is better preserved than the type, but in the same sort of limestone, and while it is merely labeled "Chouteau limestone, Pettis county, Missouri," it probably came from the same locality as the type. A third specimen, No. 6222, is recorded merely from the Kinderhook beds of Burlington, Iowa. The material in which it is preserved is a buff or yellowish, rather finely crystalline limestone, the position of which in the Kinderhook section at Burlington is probably near the top, between the oolitic limestone and the buff magnesian bed, which lies immediately below the Burlington limestone of Osage age, or in the basal portion of the oolite bed. This horizon may then be correlated with the Chouteau limestone of central Missouri.

A fourth specimen of *P. gorbyi* was studied by the writers in the collection of Fred. Braun, of Brooklyn, N. Y. It came from the Kinderhook goniatite bed of Rockford, Indiana, associated with *Prolecanites lyoni* Meek and Worthen, *Aganides rotatorius* de Koninck, *Muensteroceras oweni* Hall, *M. parallelum* Hall, and thus is certainly in the zone of *Aganides rotatorius* of the Tournaisian horizon of the Lower Carboniferous.

A fifth specimen of the genus, No. 6223, belongs to a new species (*P. praematurus* Smith and Weller). It came from the Kinderhook goniatite beds of Rockford, Indiana.

Geologic horizon.—Since this genus occurs in the same horizon, in rocks of different lithologic character, and in three localities separated by hundreds of miles, it may be considered as characteristic of the Chouteau limestone horizon of the Lower Carboniferous, equivalent to the lower part of the Tournaisian horizon of the European Dinantian formation. At present *Prodromites* is unknown outside of America, and but two species are known, in the Mississippi valley region, from the three localities mentioned.

Prodromites gorbyi Miller. Plate VI, Figs. 1. Plate VII, Fig. 9. Plate VIII, Figs. 1, 2.

1891 *Goniatites gorbyi* Miller, Adv. Sheets, Seventeenth Rep. Geol. Survey of Indiana, p. 90. Plate XV, Fig. 1.

1892 *Goniatites gorbyi* Miller, Seventeenth Rep. Geol. Survey of Indiana, p. 700. Plate XV, Fig. 1.

Neither the description nor the figure given by Miller of this type is accurate, the drawings of the septa being entirely too generalized.

[1] The numbers refer to the Walker Museum collection.

The form is laterally compressed, involute, discoidal, with very narrow umbilicus. The abdomen is narrow, and surmounted by a high narrow hollow keel, which however is usually not preserved. Where the keel is broken away the abdomen is narrow, less than a millimeter wide, with angular edges. The sides are smooth, devoid of constrictions, ribs, or other ornamentation, so far as could be determined from the casts.

The septa are complex, ceratitic, with many lobes and saddles. The ventral lobe is long and undivided. The external saddle is rounded and shorter than the laterals. The first lateral lobe is serrated, four-pointed; the second, four-pointed; the third, the three-pointed; the fourth, irregularly three-pointed; the fifth irregularly bifid. With the sixth lateral lobe begins the auxiliary series of goniatitic lobes, which are of irregular size, and eight in number, growing smaller towards the umbilicus. These characters could not be made out distinctly on Miller's type specimen No. 6208, but the details were clearly seen on specimen No. 6474, from the same locality. The differences between the two specimens, at a casual glance, might seem to be specific, but closer study shows them to be due to difference of preservation, and to different sizes at which the septa are seen. The type specimen shows the keel only at a few places on the periphery, and so indistinctly that Miller overlooked it, while No. 6474 shows the keel, 3½ millimeters high, entirely around the periphery. On both specimens the body chamber is incomplete and occupied a little over a quarter of the last revolution. It is not known what was the shape of the aperture, how long the body chamber was, when the keel began, nor what the internal lobes were like, since none of the specimens available sufficed to settle these questions.

A smaller specimen, No. 6222, from the Kinderhook beds of Burlington, Ia., showed much simpler septa, and the narrow angular abdomen with the keel broken off. It is undoubtedly in the beginning of the mature stage of growth, and was of value in showing the shape of the cross-section, since both sides were free from the matrix, while in all other specimens one side was fixed to the matrix.

At present there are known only four specimens of *Prodromites gorbyi*.

1. Miller's type, from the Chouteau limestone at Pin Hook Bridge, Pettis county, Missouri. No. 6208, Paleontological Collection, Walker Museum, University of Chicago. This is the type of the genus *Prodromites* Smith and Weller.

DIMENSIONS

Diameter	114^{mm}
Height of last whorl	64
Height of last whorl from the preceding	35
Width of last whorl	..
Involution	29
Width of umbilicus	4

2. Specimen obtained from Professor G. C. Broadhead, Chouteau limestone, Pettis county, Missouri, probably from the same locality as the last. No. 6474, Paleontological Collection, Walker Museum, University of Chicago.

DIMENSIONS

Diameter - - - - - - - - -	117^{mm}
Height of last whorl - - - - - - -	68
Height of last whorl from the preceding - -	38
Width of last whorl - - - - - - -	. .
Involution - - - - - - - - -	30
Width of umbilicus - - - - - - -	5 ?

3. Specimen from the Kinderhook limestone of Burlington, Ia., near the top of the Kinderhook Series as exposed at that locality. No. 6222, Paleontological Collection, Walker Museum, University of Chicago.

DIMENSIONS

Diameter - - - - - - - - -	75^{mm}
Height of last whorl - - - - - - -	42
Height of last whorl from the preceding - -	25
Width of last whorl - - - - - - -	10
Involution - - - - - - - - -	17
Width of umbilicus about - - - - -	4

4. Specimen from the Kinderhook goniatite limestone of Rockford, Ind.; in the paleontological collection of Fred. Braun, of Brooklyn, N. Y., where it was examined by the writers. Its dimensions are about the same as of the two specimens from Missouri.

Prodromites praematurus sp. nov., Smith and Weller. Plate VIII, Figs. 3, 4.

Type is specimen, No. 6223, Paleontological Collection, Walker Museum, University of Chicago. Form laterally compressed, discoidal, involute, deeply embracing, with narrow umbilicus, narrow slightly flattened abdomen surmounted by a hollow keel three millimeters high. Whorl indented by the preceding whorl to a little over one third of its height. Surface smooth, so far as known.

The septa are complex, ceratitic, with rounded entire saddles, serrated lateral lobes, and a series of auxiliaries above the umbilicus. The ventral lobe is narrow, and undivided; the first lateral is longer, and three pointed; the second lateral, four-pointed; the third lateral, bifid; the fourth lateral, bifid, but more deeply so than the third; then begins a series of auxiliary lobes, undivided and pointed, seven in number.

The only species with which *Prodromites praematurus* might be compared is *P. gorbyi*, from the same horizon; but in *P. praematurus* the abdomen is slightly broader, the shell rather thicker, the septa rather more complex, and the umbilicus slightly wider than on *P. gorbyi* at the same diameter. In the figures and the descriptions of the septa a difference between the two species may easily be seen.

DIMENSIONS

Diameter	62mm
Height of last whorl	34
Height of last whorl from the preceding	21
Width of last whorl	9.5
Involution	13
Width of umbilicus	6.5

This specimen was septate throughout, so the length of the body chamber could not be ascertained.

Only a single specimen is known, No. 6223, of the Paleontological Collection, University of Chicago, from the Kinderhook goniatite limestone of Rockford, Indiana.

CONCLUSION

In *Prodromites* we have the oldest known ammonite and the most complex ammonoid yet described from strata older than the Permian, occurring only a short distance above the base of the Lower Carboniferous. In all probability the ancestors of this genus had already become ammonites before the close of the Devonian, but we do not know where to look for them. The Kinderhook ammonoid fauna is exotic in America, and seems to be exotic wherever it is known. But in the faunal region from which this migration came we may expect to find a highly specialized fauna of which those forms that made their way into Europe and America in Tournaisian time are but a fragment. We have, as yet, no clue as to where this region was, but the vast unexplored Paleozoic stretches of Asia lead us to hope for much new information when that continent shall be thoroughly investigated.

The occurrence of such forms as *Prodromites*, without local ancestors serve only to emphasize our ignorance of the ancient zoology of regions outside our own, and should stimulate research in geographic distribution of fossil faunas.

JOUR. GEOL., Vol. IX, No. 3 Plate VI

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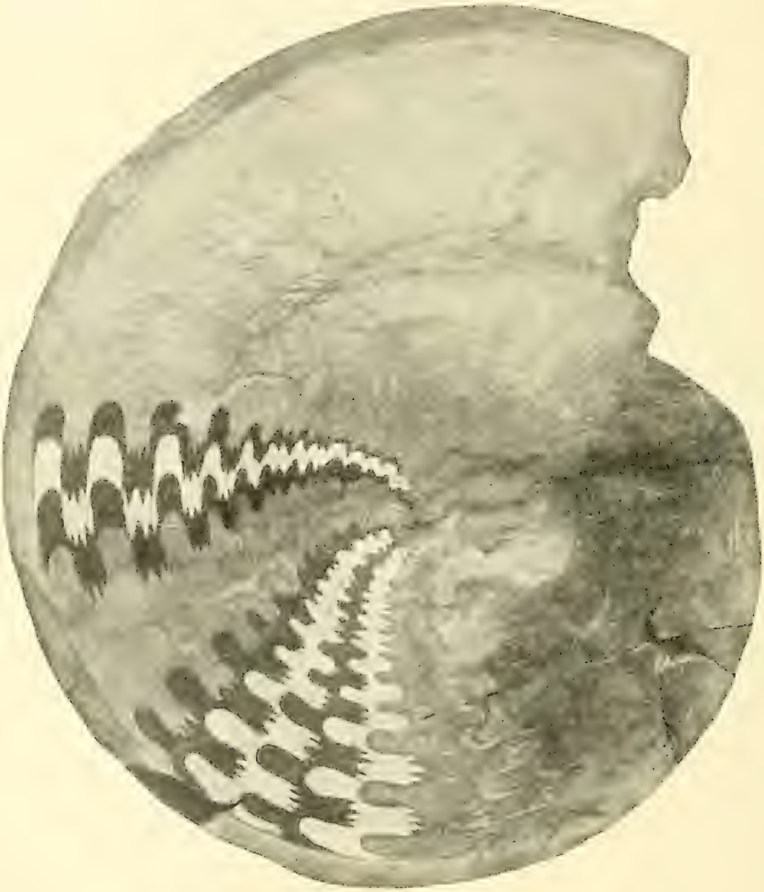
Jour. Geol., Vol. IX, No. 3 Plate VII



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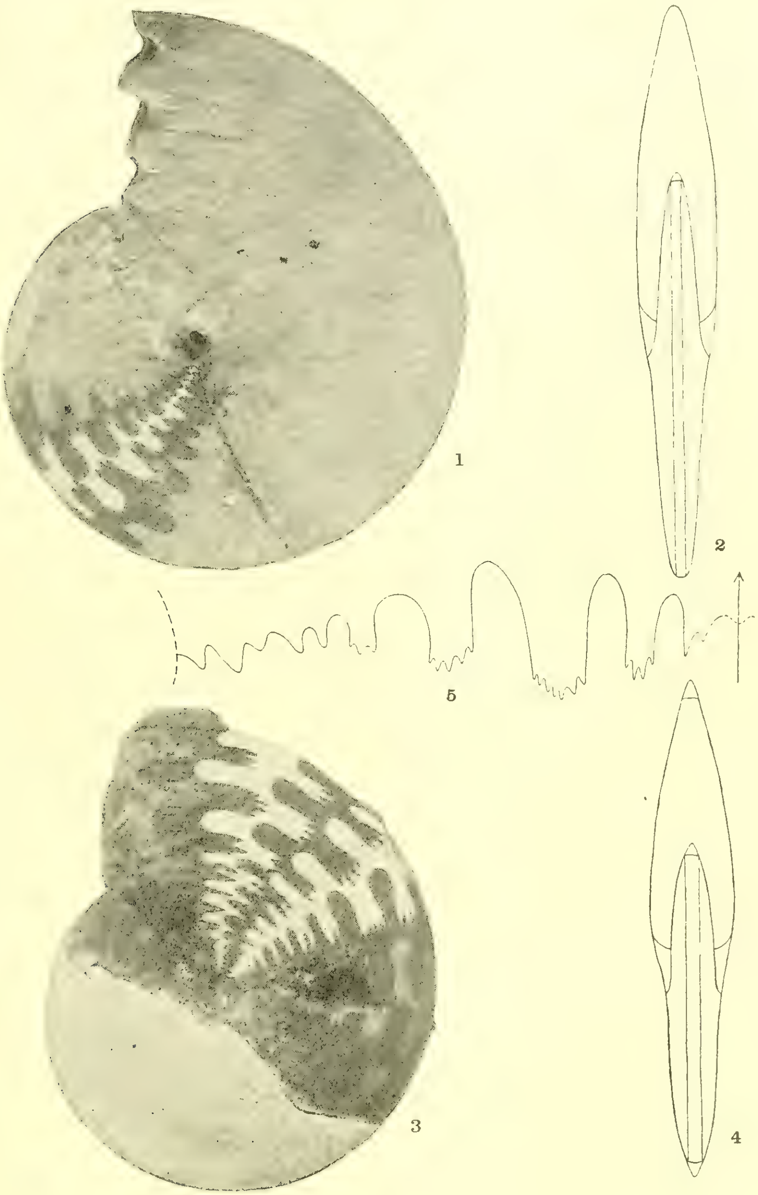
Jour. Geol., Vol. IX, No. 3 Plate VIII



EXPLANATION OF PLATES

(All figures are natural size)

PLATE VI

FIG. 1. *Prodromites gorbyi* (Miller). No. 6208 Pal. Coll. Walker Museum. Miller's type specimen from the Chouteau Limestone, Pin Hook Bridge, Pettis county, Missouri.

PLATE VII

FIG. 1. *Prodromites gorbyi* (Miller). No. 6474 Pal. Coll. Walker Museum. From the Chouteau Limestone, Pettis county, Missouri.

PLATE VIII

FIG. 1. *Prodromites gorbyi* (Miller). No. 6222 Pal. Coll. Walker Museum. From the Kinderhook beds, Burlington, Iowa.

FIG. 2. Front view of the same.

FIG. 3. *Prodromites praematurus* sp. nov. Smith and Weller. No. 6223 Pal. Coll. Walker Museum. From the Kinderhook Goniatite bed, Rockford, Indiana.

FIG. 4. Front view of the same.

FIG. 5. Septa of *Hedenstroemia mojsisovicsi* Diener. After C. Diener, Pal. Indica, series 25, Vol. II, Part II, Plate XX, Fig. 1*c*.

JAMES PERRIN SMITH,
STUART WELLER.

EDITORIAL

In the death of Dr. George M. Dawson, director of the geological survey of Canada, American geology has lost one of its ablest representatives. Not only as an individual worker, but as an administrator, he displayed unusual capacity and gave promise of still larger achievements in the future. That so promising a career should be cut short so suddenly at the climax of its productiveness is sad indeed, and the loss is keenly felt by the scientific world. When the vastness of the area whose investigation was being conducted under his direction, and its important relations to many of the great outstanding problems of geology, are recalled, the misfortune of the interruption of his successful administration and of his personal labors is most fully realized.

Dr. Dawson enjoyed unusual privileges of education and early association, which, combined with his native capacity for absorption and assimilation, gave him an unusual breadth of learning and catholicity of interest, and these qualities were called into active and manifold expression in the exposition of the broad and complex phenomena of the great Canadian field. He was gifted with notable literary abilities, and these, combined with a charming personality, gave grace and geniality to all his presentations. We hope to present a critical sketch of his work in a future number. T. C. C.

It is a hopeful sign for the future terminology of our science that manifestations of dissatisfaction with its current nomenclature are just now taking on active and declared forms. During the last few weeks conferences have been held in different quarters at which the improvement of existing usage has been the special subject of discussion. It is not proposed to dwell upon these here, though it is hoped that the JOURNAL may have

something further to say upon the subject at an early date, but merely to say a word on the special issue raised by the articles of Messrs. Cumings and Siebenthal in this number, which appear together by mutual concurrence. These articles bring up the question how far the law of priority, rigorously interpreted, shall determine all subsequent usage, and how far other considerations may properly weigh against it. It appears that in this case the term "Bedford" was used by Owen as early as 1862 in describing the well-known Indiana formation; but that it was not then formally proposed as the scientific name of the formation. In 1870 Dr. Newberry proposed the name "Bedford shale" for an entirely different formation, found at Bedford, *Ohio*. Since then the term "Bedford stone" has become familiar throughout the country as the commercial designation of the rock so extensively shipped from the Indiana town, and this use will quite certainly continue in spite of any technical usage which geologists may propose. Two practical questions therefore arise:

1. Does the familiar use of a term in an official report as the designation of a given formation in any sense or to any degree preoccupy the term so that it may not be used advisedly as the formal name of any other formation, particularly a formation in the same geological province? Specifically, did the use of the term "Bedford rock" by Owen in any degree preoccupy the term "Bedford" so that it was improperly selected as the formal name of a formation in Ohio?

2. Does the growth of such a name into very common usage, together with the certainty that this common usage must prevail in spite of any technical practice that may be adopted by geologists, constitute a sufficient reason for not applying the term technically to any other formation in the same province?

There is also the more general question, whether our science should be burdened for all time to come by infelicities in the choice of a name made by a busy worker who may have been able to give but a passing thought to the selection of a name, and who may have been unaware at the time of the infelicities likely to arise out of it. In short, shall the rule of priority, rigidly

and technically interpreted, be observed for all time, however infelicitous it may prove to be?

These are questions upon which at present there are differences of opinion. It seems altogether wise to keep them in a state of agitation until geological opinion shall formulate itself on mature and permanent grounds. We are passing from the initial stages of our science, in which the discovery of formations, like the discovery of animal and plant species, has predominated, into a more mature stage, in which these elements will lose their importance through the recognition of gradations, of evolutions, and of those broader and profounder relationships which will constitute the really important phases of the subject to future students. It is fitting, therefore, that we should consider whether the verbal lumber that may have had importance in the initial stages shall be transmitted, without modification or adaptive evolution, to the whole future of the science. To the writer it seems important to the future of the science that its language should be developed along the lines of greatest serviceability and esthetic merit. It seems, furthermore, quite possible to give all due honor to the initial discoverer without injury to the language of the science; indeed, it would seem in some instances that the initial discoverer would be honored by the rejection or the modification of his unfortunate nomenclature. Is it not within the limits of permissible practice to set aside an unfortunate name and to substitute a new one, and at the same time leave the credit of primal identification to the original author? It does not seem that priority of discovery and of description is inseparably connected with priority of nomenclature.

It is not the purpose of this note, nor the policy of the Journal, to urge at once a decision in this special case or in similar cases, but rather to urge that the question of nomenclature be kept open and be the subject of thoughtful study until all of the considerations that should enter into the formation of the language of the science have been brought forth into distinct recognition and have been duly pondered. After

sufficient time has been allowed for a deliberate consideration on these broader lines, and a consensus of opinion has been matured as a result, general rules may perhaps be reached. Meantime a measure of freedom may be allowed to individual judgment. T. C. C.

THE writer has read the proof of the article "On the use of the term Bedford limestone," by Mr. C. E. Siebenthal, which appears in this number of the *Journal of Geology*. Mr. Siebenthal's argument in reference to "the prior claims of Indiana to Bedford as a formation name" rests entirely upon the occurrence of the term "Bedford rock" in Owen's report on Lawrence county, published in 1862, which we have shown was *not* used in the sense of a formation name and was not described. The sentence in which "Bedford rock" occurs is as follows: "The Bedford rock has long been celebrated for its excellent qualities as a building stone, and is extensively shipped; additional localities are being opened, and only require the liberality of railroad directors to furnish switches and other facilities for still more extended sales."[1] The name was used in the same sense as the names of hundreds of other towns have been applied to the rock quarried in their vicinity but without any intention to have them serve as the names of geologic units. If they were recognized as formation names the number of synonyms for the consideration of the stratigraphical geologist would be enormously increased.

Bedford shale was published as the name of a geological division by Dr. Newberry in 1870[2] and fully described by him in 1873.[3] Following the single occurrence of "Bedford rock" in Owen's report the next citation of "Bedford stone" by Mr. Siebenthal is from the Indiana report for 1873, published in 1874,[4] in which Professor John Collett described the "Geology

[1] Rept. Geol. Reconnoissance Indiana, 1862, p. 137.

[2] Rept. Geol. Surv. Ohio, Pt. I, Rept. Progress in, 1869, p. 21.

[3] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, pp. 188, 189.

[4] Fifth Ann. Rept. Geol. Surv. Indiana made during the year 1873–4, p. 276.

of Lawrence county" and under the geological division of the St. Louis limestone, which was composed of beds No. 24–17 inclusive, he stated that "bed No. 22, is the quarry bed which furnishes in unlimited supply the famous 'Bedford stone' so favorably known. . . . . This stone is composed almost wholly of minute fossils cemented with shell and coal dust. It varies in color from gray to a creamy white, and may be quarried in blocks or columns the entire thickness (12 feet) of the stratum."[1] Under the geological section of the county bed No. 22 is described as "White quarry limestone" from 4 to 12 feet in thickness.[2] It is evident on reading the report that Professor Collett did not use the term "Bedford stone" as the name of a geologic unit. Furthermore, this report and the following citations by Mr. Siebenthal have no bearing upon the question of the priority of Bedford as a formation name because they are all antedated by Dr. Newberry's precise delimination and description of the Bedford Shales of northern Ohio.

Mr. Siebenthal's second point that "to the trade, *Bedford stone* it will be to the end of the chapter" does not appear to the writer to have any particular bearing upon the question. He does not believe when a scientific classification and one used in trade fail to agree that it is necessary for the former to withdraw in favor of the commercial one. A still more striking example of the difference between the trade and geological name is that of the "North or Hudson River bluestone," the trade name used for the sandstone so largely employed for flagging and house trimmings in New York and other eastern cities. The trade name was in use before the rocks of eastern New York were classified; but the geologists did not use it for the name of a geological division, although the name Hudson River group was used for an older formation than the one in which the quarries were located. The belt of country containing this "bluestone" extends for nearly one hundred miles north and south on the western side of the Hudson River and the early quarries were in

[1] Fifth Ann. Rept. Geol. Surv. Indiana made during the year 1873–4, p. 276.

[2] Loc. cit., p. 265.

rocks of the Hamilton formation. As these were partially exhausted new quarries were opened to the westward in rocks of the Sherburne formation, and later farther west in the Catskill Mountain region in rocks of the Catskill formation. At the present time the greater part of the "bluestone" is obtained from the Sherburne and Catskill formations; but to the trade it is all generally known and sold as the "Hudson River bluestone."

The name Bedford shale was given by Dr. Newberry to the geologic unit which is well exposed at Bedford village, southeast of Cleveland. The formation varies in thickness from fifty to one hundred feet; is sharply defined lithologically with its base resting on top of the black Ohio shale while its top is marked by the base of the Berea grit. In distribution it extends from eastern Ohio across the northern part of the state to Huron county, and thence south across the state to the Ohio River and into Kentucky. At a few localities in northern Ohio, especially near Cleveland, the shale includes from fifteen to twenty feet of valuable sandstone which is used considerably in that city for flagging and building stone. The Bedford shale of Ohio is as thick a formation as the Bedford limestone of Indiana; lithologically it is more sharply limited; it has, apparently, as great areal distribution; as the name of a definite geologic division it has appeared in geological literature for a longer time and to a much greater extent; but it does not contain as valuable economic deposits of building stone.

CHARLES S. PROSSER.

May 2, 1901.

Reviews.

The Norwegian North Polar Expedition, 1893–1896. Scientific Results. Vol. II. Edited by Fridtjof Nansen. Longmans, Green & Co., London, New York, 1901. VI. H. Geelmuyden, *Astronomical Observations*, pp. 1–136, with two charts. VII. Aksel S. Steen, *Terrestrial Magnetism*, pp. 1–196, with 17 plates. VIII. O. E. Schiøtz, *Results of the Pendulum Observations and some Remarks on the Constitution of the Earth's Crust*, pp. 1–90.

The astronomical observations have their chief geological value in the accurate determination of localities. While they are thus fundamental and indispensable, they afford in themselves little matter of note for the reviewer. The observations were chiefly made by Captain Sigurd Scott-Hansen. They are abundant and bear evidence of having been taken with accuracy, and they thus contribute a valuable precision to all other observations dependent upon locality.

The second part of the volume is devoted to the discussion of the magnetic observations of the expedition, which were also made by Scott-Hansen. Concerning the value of these observations, Mr. Steen remarks: "It is of especial importance to obtain determinations of the magnetic elements from the polar regions, because the observations have naturally hitherto been rather scarce from these deserted wastes, containing large tracts where the foot of man has never yet trod, and whose physical conditions place all kinds of difficulties in the way of delicate scientific investigations. They are also important because the action of the earth's magnetic forces in these very regions, judging from the observations that have been obtained, presents peculiarities to which there is no parallel in the temperate and torrid zones." The general results are summarized in tables giving the declination, horizontal intensity, and inclination at the numerous localities of observation.

The third part, which relates to pendulum observations, has, without doubt, the greatest interest for geologists. These pendulum

observations are the first systematic determinations of the force of gravity over the great ocean depths. "The observations show that the gravity may be regarded as normal over the polar basin ; and as it is not probable that this is a peculiarity of the Polar Sea, we are led to the assumption that the force of gravity is normal all over the great oceans. The increased attraction observed on oceanic islands must therefore only be due to the local attraction of the heaped-up masses at the bottom of the ocean that form the islands" (p. 63). This determination of the normal character of the force of gravity over the ocean depths, if its theoretical extension to all the ocean basins be justified, must be regarded as a contribution of the first order. The determination in the polar basin was made possible by the relative fixity of the vessel in the ice. The tremors which more or less constantly affect the polar ice sheets may perhaps have slightly influenced the results but probably in no serious way. Regarding the theoretical extension, it is however to be noted that these polar observations were nowhere made at a great distance from the edge of the continental plateau, and that the extent of the depression is undetermined, and that, furthermore, the depth of the sea is somewhat less than the average depth of the ocean. The polar basin is probably not, at most, much greater in extent than the Mediterranean basin, and may be much less. It would seem, therefore, that some reserve may be prudently exercised in accepting the assumption that the observations in the Polar Sea determine the force of gravity over the great ocean depths in general. In view of the importance of determining this beyond question, it may be suggested that attempts be made to make pendulum observations in the calm belts of the tropics. This suggestion is made on the assumption that the sea might there be found sufficiently calm to permit observations of approximate accuracy.

The discussion of the crust of the earth, which follows that of the pendulum observations, is less satisfactory than it might have been, owing to the limitation of the theoretical assumptions to a single line of hypothesis. Apparently the results might be appreciably different, if different hypotheses of the internal constitution of the earth had been assumed. The discussion proceeds upon the conception that all the differences in the density of the solid portion of the earth are confined to its superficial portion. This is doubtless in accord with present majority views based on deductions derived from prevalent theories as to the origin and early state of the earth, but it is none the

less unsatisfactory, because it involves some assumptions which are apparently incompatible with the necessary deductions of physics, and which must probably be abandoned, whatever may happen to speculative views of the earth's genesis. For example, it is assumed that there is now an inner nucleus of uniform density forming a perfect spheroid, and that the outer surface that is now the ocean bottom was originally nearly or quite on a level with that on the continents, and that the present oceanic depressions are the result of progressive sinking due to cooling. Lord Kelvin, however, is authority for the statement that "there seems to be no possibility that our present day continents could have risen to their present heights, or that the surface of the solid in its other parts could have sunk down to their present ocean depths, during the twenty or twenty-five million years which may have passed since the *consistentior status* began or during any time however long." (On the Age of the Earth as an Abode Fitted for Life, p. 706.) And this conclusion is supported by independent considerations. The thickness of the earth's crust is taken by Professor Schiøtz to be 0.02 of the earth's radius, or about eighty miles. If as supposed it rests upon a spheroidal nucleus of uniform density and perfect form, the difference in thickness in different parts amounts to fully 10 per cent. of its own thickness when reckoned only between plateaus and antiplateaus, neglecting mountain heights. A *difference* of contraction to the amount of 10 per cent. is quite incredible, as is also any remote approach to this amount. The *average* difference between the thickness of the crust beneath the continental plateaus and that beneath the ocean bottoms is, under the assumption made by the author, more than 3 per cent. of the whole crustal thickness, and this is more than can reasonably be attributed to any *difference* in contraction due to cooling. In view of these and other considerations, it would have been more satisfactory if the discussion had been extended to the postulates of other hypotheses of the inner constitution of the earth: among them, the assumption that an uneven distribution of density reaches to profound depths.

Nevertheless, it is a great gain to the study of the earth's dynamics that a treatment of the problem from the point of view of pendulum data extended to the ocean surface has been ventured, even though it be confined to a single line of hypothetical postulates.

T. C. C.

Meteorological Observations of the Second Wellman Expedition. By EVELYN B. BALDWIN, Observer, Weather Bureau. Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900. Part VII. Washington, 1901.

This report embraces in full detail the meteorological observations made by Mr. Baldwin in connection with the second Wellman expedition. The observations relate especially to the meteorological conditions at and in the vicinity of Franz Josef Land, from June 1898, to August 1899, embracing observations made on shipboard between Tromso, Norway, and Franz Josef Land, those made at Harmsworth House and at Fort McKinley, on Franz Josef Land, and those made in the field, partly on Franz Josef Land and partly on the ocean north of there. To atmospheric geologists, the summations relative to the prevalent direction of the wind and cloud movements will perhaps possess the greatest interest. These show that the prevalent atmospheric movement was emphatically from the northward. The observations upon the upper clouds, which perhaps best express the general movement, may be grouped as follows :

N. W. - - - -	19 per cent.	
N. - - - -	20 per cent.	
N. E. - - - -	19 per cent.	
E. - - - -	10 per cent.	
	——— - -	68 per cent.
S. E. - - - -	4 per cent.	
S. - - - -	2 per cent.	
S. W. - - - -	2 per cent.	
W. - - - -	6 per cent.	
	——— - -	14 per cent.
Calms - - - - - -		18 per cent.

Fifty-eight per cent. are from N. W., N., and N. E., while only 24 per cent. are from the remaining five points.

Separating these into those that have an easterly and westerly component, the observations take this form :

North - - - - - -		20 per cent.
With easterly component:		
N. E. - - -	19 per cent.	
E. - - -	10 per cent.	
S. E. - - -	4 per cent.	
	——— - -	33 per cent.

With westerly component:		
N. W. - -	19 per cent.	
W. - - -	6 per cent.	
S. W. - -	2 per cent.	
	—— - -	27 per cent.
South - - - - - -		2 per cent.
Calm - - - - - -		18 per cent.

From these data it will be seen that there is but very slight preponderance of the easterly component over the westerly, and that the aggregate direction is almost due north.

Analyzing in a similar way the observations on the lower clouds, we have:

N. W. - - - -	13 per cent.	
N. - - - -	20 per cent.	
N. E. - - - -	25 per cent.	
E. - - - -	5 per cent.	
	—— - -	63 per cent.
S. E. - - - -	7 per cent.	
S. - - - -	6 per cent.	
S. W. - - - -	15 per cent.	
W. - - - -	6 per cent.	
	—— - -	34 per cent.
Calm - - - - - -		4 per cent.

Summing up with reference to eastward and westward components, we have the following:

North - - - - - -		20 per cent.
With easterly component:		
N. E. - - -	25 per cent.	
E. - - -	5 per cent.	
S. E. - - -	7 per cent.	
	—— - -	37 per cent.
With westerly component:		
N. W. - -	13 per cent.	
W. - - -	6 per cent.	
S. W. - -	15 per cent.	
	—— - -	34 per cent.
South - - - - - -		6 per cent.
Calm - - - - - -		4 per cent.

The result is practically the same as before.

The emphatic preponderance of northerly winds, and the slightness of the average deviation to the east over that to the west, are

points of interest and should receive the consideration of the advocates of a "circumpolar whirl." Of course, conclusions are not to be drawn from these limited data (and data taken in an expedition of this kind are necessarily limited), but they are in consonance with many other data that invite a reconsideration of prevalent theories of atmospheric circulation.

When the conditions under which these observations were made are considered, their number and their nature must be regarded as a high tribute to the scientific devotion of the observer.

T. C. C.

The Oriskany Fauna of Becraft Mountain, Columbia County, N. Y. By J. M. Clark, Ph.D., Mem. N. Y. St. Mus., No. 3, Vol. III.

Becraft Mountain is an outlier composed chiefly of strata of early Devonian age, resting conformably upon the upturned slates of the Hudson River formation. A preliminary paper on the fauna of the Oriskany formation at this locality was published in 1899 by Professor C. E. Beecher, being accompanied by a list of the species present identified by the author of the present report. It was shown at that time that the fauna was a peculiar one, consisting of an intermingling of Helderbergian and Oriskany forms. The present report is a detailed description of the fauna accompanied by good illustrations of all the species.

This discussion of the Becraft Mountain Oriskany fauna by Dr. Clark, brings clearly into view a very different conception of the faunas of Oriskany age in eastern North America from that which has become known through Volume III of the New York Paleontology. At Becraft's Mountain, and in strata extending southward through New York and into New Jersey, a calcarious facies of Oriskany sedimentation occurs, which contains a very different assembly of organisms from that of the original Oriskany sandstone, and which is considered by Dr. Clark as being the normal fauna of the period. In this connection Dr. Clark writes: "In the earlier presentation of this fauna it was regarded as of Lower Oriskany horizon, on account of the presence of many Helderbergian species, but we believe it will be more correctly construed as the representation of the proper and normal Oriskany fauna, the true fauna of this time unit inclosed in the sediments of its proper habitat."

The character of the Oriskany sandstone deposits in New York

from Schoharie county westward are shown to be "a series of arenaceous lenses connected by thin sheets of quartzitic sandstone." In regard to the fauna of these lenses, it is said: "The great brachiopods, *Spirifer arenosus*, *Rensselaeria ovoides*, *Hipparionyx proximus*, and *Meristella lata*, with *Tentaculites elongatus*, which are the species generally present in these lenses, could not have had their habitat on such a deposit and in a sea whose depth favored such deposition. We shall not be wrong in regarding these accumulations of remains in the true Oriskany sandstone as agglomerations, swept out of their facies and away from the more calcareous, deeper water deposits of the time. To regard them as species of the sandy facies of Oriskany time would, I believe, be altogether erroneous. They appertain truly to the calcarious facies and the normal fauna of the Oriskany time."

In the summation of the fauna, ninety-four clearly defined species are recognized, of which "thirty-eight represent expressions of species which began their existence in Helderbergian time; on the other hand but eighteen species of the fauna continue their existence or appear to be represented by closely allied forms beyond the close of the Oriskany sedimentation." Twenty-nine species of the fauna are recognized in the arenaceous Oriskany beds.

The evidence afforded by this fauna as the true Siluro-Devonian boundary line is of much importance. No one disputes the Devonian age of the Oriskany formation, and this fauna demonstrates that there is no natural faunal break in passing from the Helderbergian to the Oriskany, as there should be if the Helderbergian was excluded from the Devonian.

The closing pages of the report are devoted to somewhat minute discussion of the Silurian and Devonian characteristics of the Helderbergian fauna, both the positive and the negative elements being considered, and to a discussion of the stratigraphic argument based upon the relationships of the Maulius limestone.

S. W.

Recent Publications

—Abbe, Cleveland, Jr. The Physiographic Features of Maryland. [Reprinted from the Bulletin of the American Bureau of Geography, Vol. I, 1900.]

—Adams, Frank D. Memoir of Sir J. William Dawson. [From Bulletin of the Geological Society of America, Vol. XI, 1899.]

On the Probable Occurrence of a Large Area of Nepheline-Bearing Rocks on the Northeast Coast of Lake Superior. [Reprinted from the Journal of Geology, Vol. VIII, No. 4, 1900.] The University of Chicago Press.

—Adams, F. Dawson, and John T. Nicholson. An Experimental Investigation into the Flow of Marble. Philosophical Transactions of the Royal Society of London, Series A, Vol. CXCV, pp. 363–401. Plates 22–25. Dulau & Co., 37 Soho Square, W., London, 1901.

An Experimental Investigation into the Flow of Marble (Abstract.) From the Proceedings of the Royal Society, Vol. LXVII. Read June 21, 1900.

—Ami, Henry M. On the Geology of the Principal Cities in Eastern Canada. [From the Transactions of the Royal Society of Canada, Second Series, 1900–1, Vol. VI, section 4, Geological and Biological Sciences.]

On a New or Hitherto Unrecognized Geological Formation in the Devonian System of Canada. [Reprinted from the Canadian Record of Science, Vol. VIII, No. 5, for January 1901.]

Synopsis of the Geology of Canada (being a Summary of the principal terms employed in Canadian geologic nomenclature). [From the Transactions of the Royal Society of Canada, Second Series, 1900–1, Vol. VI, section 4, Geological and Biological Sciences.] Issued March 25, 1901.

—Australasian Institute of Mining Engineers, Proceedings of. Annual Meeting, Melbourne, January 1901.

—British Association for the Advancement of Science, Report of the Seventieth Meeting, held at Bradford in September 1900. John Murray, London, 1900.

—Burr, Henry T. The Structural Relations of the Amygdaloidal Melaphyr in Brookline, Newton, and Brighton, Mass. Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXXVIII. Geological Series, Vol. V, No. 2. With 2 plates. Cambridge, Mass., 1901.

—Canadian Pleistocene Flora and Fauna. Report of the Committee, consisting of Sir J. W. Dawson (chairman), Professor D. P. Penhallow, Dr. H. Ami, Mr. G. W. Lamplugh, and Professor A. P. Coleman (secretary), reappointed to continue the investigation of the Canadian Pleistocene Flora and Fauna. I. On the Pleistocene near Toronto, by Professor A. P. Coleman. II. On the Pleistocene Flora of the Don Valley, by Professor D. P. Penhallow.

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GLACIAL AND INTERGLACIAL BEDS NEAR TORONTO

An article on the present subject was published in 1895 in the JOURNAL OF GEOLOGY;[1] but the five years since that time have added so much to the completeness of our knowledge of this important Pleistocene area as to justify a fresh account of the region. At the Toronto meeting of the British Association in 1897 the series of interglacial beds for which Professor Chamberlin had suggested the name "Toronto Formation" aroused so much interest that a committee was appointed for its investigation and grants were made at this and the two following meetings to cover the expense of excavations to solve some problems in connection with the beds. The final report of the committee, prepared by its secretary, the present writer, with a separate report on Pleistocene plants in Canada by Professor Penhallow, was made at Bradford in 1900, summing up the facts and giving lists of the interglacial fauna and flora, thus providing the materials for a more complete discussion of the events recorded in the "drift" of the region than has been attempted before.

The interglacial beds of Scarboro' near Toronto were first studied more than 20 years ago by the well-known English pale-

[1] JOUR. GEOL., Vol. III, No. 6, pp. 622, 645.

ontologist, Dr. George Jennings Hinde,[1] but his excellent work attracted little attention and the importance of the facts brought to light seems to have been overlooked by Pleistocene geologists. In 1894 the Don interglacial beds were described by the present writer,[2] who has since then given careful study to the numerous

FIG. 1.

and excellent sections presented by Scarboro' Heights, the ravines of the Don, and many excavations carried on in and about the city of Toronto. A large number of fossils have been collected by Mr. J. Townsend and the writer, and Professor Penhallow has determined the plant remains, Dr. Dall and his assistants the shells, and Dr. Scudder the insects. These gentlemen have shown the greatest skill and patience in working up what was often very difficult material, and much of the value of the results of the investigation is due to them, particularly in determining

[1] Canadian Journal, 1878, p. 388 *et seq.* [2] Am. Geol., Vol. XIII, 1894, pp. 85–95.

the important changes of climate indicated. In the following paper an attempt will be made to give a connected history of the events which have occurred in the Ontario basin during the time represented by the Toronto Formation and the sheets of till below and above it, generally held to belong respectively to the Iowan and Wisconsin ice advances.

RETREAT OF THE IOWAN ICE SHEET

The retreat of the Iowan ice was probably accompanied by one or more lakes similar to those whose raised beaches, formed during the retreat of the last ice sheet, are so well marked around the present great lakes. Though no remnants of Iowan beaches are known to exist, there is strong faunal evidence of at least one glacially dammed Iowan lake. When the region was ice covered, all aquatic life must have been destroyed, so that any species occurring in interglacial beds must have migrated into the region from river systems beyond the reach of the ice. The unios which are so striking a feature of the lower beds of the Toronto Formation are Mississippi forms. As there is no more proof of direct connection between the Ontario basin and tributaries of the Mississippi during interglacial times than now, we may suppose that these shellfish entered the basin in a round-about way by means of an interglacial upper lake, draining at first past Chicago into the Mississippi, but afterwards finding an outlet by the Laurentian river into the Ontario valley and thence into the gulf of St. Lawrence.

After the Iowan glacier had retreated so far that lakes dammed by it had been drained, the St. Lawrence system of waters no doubt returned to much the same channels as before the advance of the ice, since there is no evidence that any great thickness of drift had been left to block the way. The lowest till at Toronto is generally thin, running from a foot or more near the bend of the Don at the paper mill to 8 or 9 feet at the Gerrard street bridge. At one point in the west end of the city, however, 35 to 40 feet of till occur, but a well-defined "bowlder pavement," with all the stones at the same level and striated on

their upper surfaces, is found 4 or 5 feet above Lake Ontario, and perhaps indicates that the upper 30 feet are of later age than the Iowan. Farther west along the shore of the lake the till sheet is not more than 10 or 15 feet thick. So far as known, this layer of till is nowhere thick enough to have modified greatly the shape of the surface, which may now be roughly sketched.

The highest point of the Hudson River shale near Toronto is at Weston, 7 miles northwest of the city, where it reaches about 200 feet above Lake Ontario. In the Don valley the shale runs from a little below lake level near the mouth of the river to 30 feet above it 2 or 3 miles to the north; but 5 miles east of the Don a well sunk at the foot of Scarboro' Heights failed to reach the rock at 41 feet below the lake, and beyond this bedrock is not found for a long distance, first appearing at Pickering, 15 miles to the east. This implies a width of about 25 miles for the mouth of the valley occupied by the preglacial (and also interglacial) Laurentian river whose old channel from Georgian Bay to Scarboro' has been indicated by Dr. Spencer.[1] The valley narrowed somewhat rapidly, however, toward the northwest, for on the upper reaches of the River Rouge between Unionville and Markham numerous angular slabs of Hudson River rock, evidently not far from their source, are found more than 300 feet above Ontario. The distance from this point to Weston is 16 miles in a southwesterly direction, and between the two points, the ravines of the Don and wells which have been sunk prove that a channel of considerable depth existed.

[1] Duration of Niagara Falls and History of the Great Lakes, pp. 18 and 19.

Dr. Spencer's idea of a present channel 474 feet deep, running from Scarboro' Heights across Ontario to the deep water near the south shore seems founded on an erroneous sounding as marked on Bayfield's chart. A series of soundings carried out by the present writer in 1898 across the supposed deep channel showed no such interruption in the gentle southward slope of the bottom, the depth at about the position of the 474 feet sounding on the chart being 175 feet. Probably the 4 is in mistake for 1, and the true sounding was 174 feet. The old channel across Lake Ontario was filled in completely, so far as one can ascertain, by stratified clay and till in later times and so has long ago disappeared. The fact that Scarboro' Heights, rising 375 feet above the lake, have been piled up since then may be considered sufficient proof of this.

We may suppose then that the great preglacial valley, though coated with a sheet of bowlder clay by the Iowan ice, had probably much the same form and dimensions at the end of that ice invasion as before. If there was an interglacial episode similar to the postglacial lake Iroquois no certain remains of its beach deposits are known, and the level of the water when the laying down of the Toronto Formation began was not greater than that of Lake Ontario and may have been considerably beneath it; for the lowest unio beds lie more than 40 feet beneath the present lake at Scarboro'.

Before the formation of similar beds at higher levels considerable erosion took place, as at the bend of the Don where these deposits occupy an old river channel cut through the Iowan till into the Hudson River shale to the depth of at least 16 feet, as shown by a cutting of the Don, at this point 19 feet above Ontario. The bowlder clay has been cut through to the shale in the western part of Toronto also, as shown in a well bored for purposes of exploration, the bottom of the interglacial deposits being 17 feet above Lake Ontario. It seems clear that rivers had been at work for some time before the unio beds were formed.

WARM CLIMATE BEDS OF THE DON VALLEY

The earliest beds of the Toronto Formation were deposited on the eroded surface of the Iowan till or on the shales which had been laid bare beneath it by river action; and they were formed probably in the shallow waters of a lake, though some features suggest the action of currents. At the bend of the Don, coarse, little rounded shingle of the harder layers of the underlying Hudson River rocks makes the lowest bed visible above the present river, and suggests the action of a current rather than of waves. Thick sheets of vegetable matter, greatly decayed twigs, leaves, reeds, etc., with trunks and branches of trees are interbedded with the shingle, however, showing that the current could not have been swift. Possibly these beds were formed just at the mouth of a small river like the present Don, where it entered a lake standing 20 or 30

feet higher than Ontario. If this is correct there had already been a damming back of the interglacial waters to a higher level than has been reached yet in postglacial times. This damming could not have been by ice, for the climate was at least as mild as at present, since the tree trunks referred to include wood of the red cedar, an elm, the pawpaw and three species of oak; and among the shellfish there are two not reported from Canadian waters at the present day, though found in the Mississippi, Quadrula (unio) pyramidata and Anodonta grandis.[1]

As the beds at Taylor's brickyard, which have been described in former papers, have been traced as far east as the bend of the Don at the edge of the interglacial valley just referred to and also as a thin lower layer across these deposits, we may include the whole in one section, commencing with the bend of the Don as a basal series and running up through the series at the brickyard as far as the cold climate stratified clays.

SECTION AT TAYLOR'S BRICKYARD

		Feet
8.	Yellow or brown sand with some reddish clay (no fossils) -	3–60½
7.	Blue peaty clay with some gray sand (unios, wood, caribou horn) - - - - - - - - - - - -	4½–57½
6.	Yellow to brown sand with thin layers of purplish clay (shells) - - - - - - - - - - -	14–53
5.	Fine gray and yellow sand (unios and other shells) - -	3–39
4.	Blue stratified clay and sand (unios with other shells and logs of wood), above 2½ feet of bowlder clay resting on Hudson River shale - - - - - - - - - - -	2–36

SECTION AT BEND OF DON

3.	Brown clay with sandy layers (unios, campeloma, etc.) - -	5–34
2.	Blue clay with sandy layers (unios, anodons, wood) - - -	6–29
1.	Coarse shingle with clay and peaty layers (shells and logs) -	4–23
	River Don above Lake Ontario - - - - - - -	19–19

From the combined section given above it will be seen that the warm climate beds of the Don commencing 19 feet above Lake Ontario have a total thickness of 41½ feet. It should be

[1] Notes on Can. Unionidae, J. F. WHITEAVES, Can. Rec. Science, 1895, No. 5, p. 250; and No. 6, p. 365.

added however that no fossils have been obtained from the uppermost three feet of brown sand. The lower section differs slightly in fauna from the upper one, containing numerous anodons and campelomas, which are almost absent from the beds at the brickyard; but the unios and trees are alike.

In previous papers the warm climate beds have been represented as ending just beneath the peaty blue clay (No. 7) which was considered to belong to the cool climate beds, chiefly because it contained peaty layers and had yielded a shed horn of caribou. Recently, however, the peat has been examined and found to contain no mica scales and very few mosses or spruce needles, which are very characteristic of the peaty layers belonging to clays of the cool climate. Instead of this the brown layers consist mainly of fragments of deciduous leaves. The recent finding of unios at the top of the blue clay strengthens the opinion that it and the brown sand above should be included with the warm climate beds. The lowest point at which the unio clays and sands have been found is 41 feet below Lake Ontario at the foot of Scarboro' Heights, giving a vertical range of more than 100 feet for the whole series of warm climate beds The following species have been obtained in the Don beds:

FAUNA OF WARM CLIMATE BEDS, DON VALLEY

Vertebrata: possibly mammoth or mastodon and bison, and an undetermined fish.

Arthropoda: several undetermined beetles and cyprids.

Mollusca:

Unio undulatus " rectus " luteolus " gibbosus	still living in Lake Ontario.
" phaseolus " pustulosus " trigonus " coccineus	still living in Lake Erie, but not reported from Lake Ontario.
" occidens " solidus " clavus " pyramidata	not known in the St. Lawrence system of waters, but living farther south.

Anodonta grandis, not reported from Canada.

Sphaerium rhomboideum
" striatinum
" sulcatum
" solidulum
" similis (?)
Pisidium Adamsi
" compressum
" novaboracense (?)
Pleurocera subulare
" elevatum
" Lewisi (?)
Goniobasis depygis
" Haldemani
Limnaea decidiosa
" elodes
Planorbis parvus
" bicarinatus
Amnicola limosa
" porata
" sagana
Physa heterostropha
" ancillaria
Succinea avara
Bythinella obtusa
Somatogyrus isogonus
Valvata sincera
" tricarinata
Campeloma decisa
Bifidaria armata (land snail)

In all there are thirty-nine undoubted species of mollusks, and three more probably, included in the fauna. Of these eight or ten have not been reported from Lake Ontario, but occur farther south.

FLORA OF WARM CLIMATE BEDS, DON VALLEY

Acer pleistocenicum
" spicatum
Asimina triloba
Carya alba
Chamaecyparis sphaeroidea
Crataegus punctata
Cyperaceae sp.
Eriocaulon sp.
Fraxinus quadrangulata
" sambucifolia
" americana
Festuca ovina
Hypnum sp.
Juniperus virginiana
Larix americana
Maclura aurantiaca
Picea nigra
" sp.
Pinus strobus
Platanus occidentalis
Populus balsamifera
" grandidentata
Prunus sp.
Quercus obtusiloba
" alba (?)
" rubra
" tinctoria
" oblongifolia
" macrocarpa
" acuminata
Robinia pseudacacia
Salix sp.
Taxus canadensis
Thuya occidentalis
Tilia americana
Ulmus americana
" racemosa
Vaccinium uliginosum

Professor Penhallow, from whose report to the British Association in 1900 this list is taken, states that "within this area no less than thirty-eight species have been recovered, and they point conclusively to the existence of climatic conditions differing materially from those which now prevail, and of a character more nearly allied to those of the middle United States of today." "Only one species appears to have disappeared in Pleistocene time. Acer pleistocenicum, which was abundant in the region of the Don, bears no well defined resemblance to existing species."

The plant remains consist chiefly of wood and leaves, the former usually much flattened from the pressure of the later ice sheet, but otherwise often well preserved, the red cedar, for instance, showing its color and being still quite tough, although some of the wood, probably decayed before being waterlogged and included in the clay, is in a worse condition. Parts of the wood are almost of the nature of brown coal breaking across easily and showing a coaly luster on the broken surfaces. It may be worthy of mention that some large bits of porous charcoal, as if from the burning of a log, were found cemented with limonite in the sand (No. 6) just under the blue clay. The leaves are preserved generally in the thinner beds of clay and are rarely obtained whole.

The sands of the Don beds vary greatly in fineness and color, and are more or less cross bedded and mixed with gravel, as if deposited under wave action; while the coarse shingle at the base of the section near the bend of the Don looks like the work of a river. The upper part of the warm climate beds of the Don, consisting of stratified clay (No. 7) and sand (No. 8) appears to have been formed under distinctly lacustrine conditions. At the beginning of the formation there may have been no lake, only a great river with a tributary or tributaries coming in from the west; but at its close there was a great lake which stood at least sixty feet above Lake Ontario at present. Whether the change in water levels was slow or rapid there is no evidence to show. That the water remained for some time

at the higher level is testified by the thorough oxidation of the iron in the upper sandy beds, which are in some layers deep brown in color, and completely cemented with limonite. The blue layers (2, 4 and 7) have retained their color because of the large amount of deoxidizing vegetable material present in them.

The change in the level of the interglacial lake effected a great change in another respect. Where the valley of the Laurentian river had existed there was now a broad and deep bay running to the north, and the great river began to spread out clay and silt derived from its upper reaches in this basin. The upper bed of blue clay may have been formed by a shifting of the current of the main river, which, however, shifted again while the highest layer of sand was formed, bringing to a close the beds belonging to the warm climate series.

The extent of the Don beds, as indicated by the typical unio sands and clays, is not known very thoroughly, owing to the depth at which they are buried in most places. They occur a few feet below Lake Ontario at Scarboro', four miles southwest of Taylor's brickyard and at Price's brickyard about half way between; and unios have been found in sandy beds of interglacial age at Adare's sand pit on Shaw street, about three miles west of Taylor's. As logs of wood have been found by well diggers at points between, there is a strong probability that the Don beds continue to that point, in which case they have a known extent from east to west of more than six miles, with a breadth from north to south of more than two miles. The real area is probably much greater than this.

THE SCARBORO' OR COOL CLIMATE BEDS

After the close of the Don period the interglacial lake deepened greatly, finally standing more than 150 feet above Lake Ontario, and a great series of clays and sands were deposited by the Laurentian river in the form of delta materials in the wide and deep bay, at this time extending still farther to the north than before. As seen at Taylor's brickyard, the clay beds, gray and finely

laminated, with a few thin peaty layers, rest conformably on the brown sand at the top of the Don beds. The thickness, however, is not great, on account of later interglacial erosion, at the

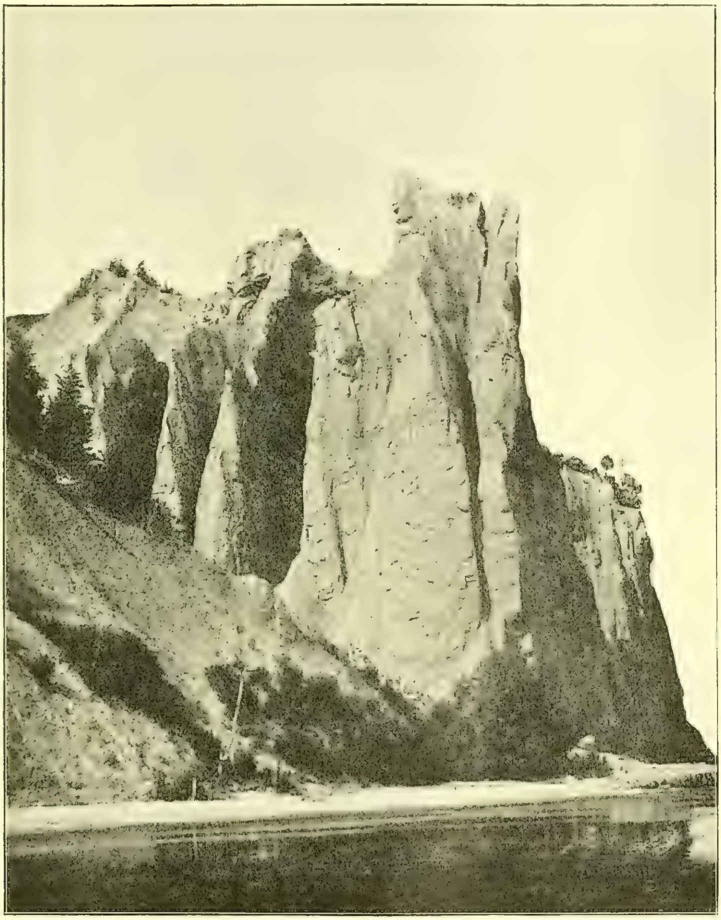


FIG. 2.—Pleistocene Cliffs of Scarboro' Heights.

south end of the clay pit only 7½ feet, 70 yards north, 13 feet, and a quarter of a mile to the northeast 30 feet. These clays are magnificently shown at Scarboro' heights, where they were carefully studied by Dr. Hinde. They commence, as shown in a

well sunk on the shore beneath the cliff, about five feet below Lake Ontario and rise 85 or 90 feet above it.[1] The upper surface mingles somewhat with the overlying sand and varies in height to some extent. The clay is gray, very firm and resistant, almost as much so as the Hudson River shale of the region, and is generally finely laminated, though there are beds from two to four or five feet thick, showing little or no lamination. Besides the fine lamination there are often thin layers of grayish silt with peaty material at distances of one or two inches apart, perhaps representing flood seasons of an annual character. These silty layers cannot often be traced for more than a few feet horizontally, and may run up or down into a bed showing no lamination in a way suggesting cross bedding. Another very characteristic feature is the presence of half inch sheets of greenish impure siderite every two or three feet, though these are not found everywhere.

The silty layers with peaty substances when washed to remove clay and then dried and looked over with a lens show great uniformity in all parts of the region. Scales of mica are always numerous, as well as mosses, spruce leaves, certain round black seeds and chitinous portions of beetles. So constant is this assemblage that these clays are easily recognized by it when found in new localities, the clay ironstone sheets affording an additional earmark. Finally these are the only clays in the region which burn to a dark red brick. As their materials must have been derived by the Laurentian river and its tributaries from the calcareous bowlder clay of the valley to the north, much of the lime must have gone into solution by superficial weathering before reaching the river or have been dissolved during the time of transport, thus allowing the red color due to iron to appear on burning.

From the peaty layers of the clay the beetles were obtained whose names are given in the following lists :

[1] B. A. A. Sc. Rept., Com. on Pleistocene of Canada, p. 3.

Carabidae (9 gen., 34 sp.)

Elaphrus irregularis
Loricera glacialis
" lutosa
" exita
Nebria abstracta
Bembidium glaciatum
" Haywardi
" vestigium
" vanum
" praeteritum
" expletum
" damnosum
Patrobus gelatus
" decessus
" frigidus
Pterostichus abrogatus
" destitutus
" fractus
" destructus
" gelidus
" depletus
Badister antecursor
Platynus casus
" Hindei
" Halli
" dissipatus
" desuetus
" Harttii
" delapidatus
" exterminatus
" interglacialis
" interitus
" longaevus
Harpalus conditus

Dytiscidae (3 gen., 8 sp.)

Coelambus derelictus
" cribrarius
" infernalis
" disjectus
Hydroporus inanimatus
" inundatus
Hydroporus sectus
Agabus perditus

Gyrinidae (1 sp.).

Gyrinus confinis LeC.

Hydrophilidae (1. sp.).

Cymbiodyta exstincta

Staphylinidae (11 gen. 19 sp.).

Gymnusa absens
Quedius deperditus
Philonthus claudus
Cryptobium detectum
" cinctum
Lathrobium interglaciale
" antiquatum
" debilitatum
" exesum
" inhibitum
" frustum
Oxyporus stiriacus
Bledius glaciatus
Geodromicus stiricidii
Acidota crenata, Fabr. (*var.* nigra)
Arpedium stillicidii
Olophrum celatum
" arcanum
" dejectum

Chrysomelidae (1 gen. 2 sp.).

Donacia stiria
" pompatica

Curculionidae (4 gen. 6 sp.).

Erycus consumptus
Anthonomus eversus
" fossilis
" lapsus
Orchestes avus
Centrinus disjunctus

Scolytidae (1 sp.).

Phloeosinus squalidens

Dr. S. H. Scudder, who determined the beetles, thinks that all but two of the 72 are extinct. Twenty-five of the number were named a few years ago from Scarboro' material sent by Dr. Hinde, the rest more recently from specimens collected at various outcrops of the peaty clay by the writer. A complete account of the new species, with figures, will be published shortly by the Canadian geological survey. The number of species of beetles could no doubt be extended if the work of determining them were not so very laborious. In addition to the beetles cyprids occur and rarely also fragments of sphaeriums.

The plants include several trees, Professor Penhallow having found Larix americana, Picea alba and another species of Picea in materials from Price's and Simpson's brickyards; while Dr. Macoun found leaves apparently of willow and alder in peaty material from Scarboro', as well as two shrubs, Oxycoccus palustris and Vaccinium uliginosum, and some smaller plants, such as equisetum, Carex aquatilis and C. utriculata. Dr. Hinde reports five species of mosses belonging to the genera Bryum, Hypnum and Fontinalis ; and Mrs. E. G. Britton adds Limnobium. Three species of diatoms, a chara and spores of lycopodium have been reported also.

Dr. Scudder judges from the relationships of the beetles to modern forms that the climate had "a boreal aspect, though by no means so decidedly boreal as one would anticipate under the circumstances." The same conclusion is reached by Dr. Macoun and by Professor Penhallow from the plant remains.

The change from the warm climate fauna and flora to the cool climate ones appears rather sudden, but may not be so in reality. The upper blue clay (No. 7) at Taylor's brickyard has yielded a caribou horn, which suggests a cooler climate than that of the trees and unios a few feet below, since no caribou are known within 150 or 200 miles to the north of Toronto at present. However, the range of the caribou toward the south may have been greater before the white man's settlements encroached on the region. On the other hand the materials of the delta deposits must have been derived largely from the regions to the north

and from a higher elevation, where at present some trees found in the Don valley are wanting, such as Platanus occidentalis, which reaches its northern limit at Toronto.

The peaty clay occupies the western part of the great bay into which the Laurentian river emptied when the interglacial lake was at its greatest height. It appears first at Rosebank, 16 miles east of the Don, and is last seen with certainty 2½ miles west of the river in a sewer on Bathurst street, making a width of 18½ miles. Dr. Hinde reports it also from the mouth of the Humber, 6 or 7 miles west of the Don, but the writer has not been able to find it there, though somewhat loesslike sandy silt containing a few plant remains, occurring near the Humber, may represent the peaty clay of Scarboro'. If so, the whole extent of the beds will be 25 miles from east to west. The last exposure known towards the north is 6½ miles inland from Lake Ontario, and no doubt if the cuttings of the Don were deep enough it would be found considerably farther north. The greatest thickness of the clay at Scarboro' is about 94 feet, 5 below the lake and 89 above; but the upper limit is rather hard to fix, since it becomes interbedded with sand. Toward the west the peaty clay rises higher, reaching 150 feet north of Reservoir Park and in the Bathurst street sewer.

INTERGLACIAL SANDS

Above the peaty clay at Scarboro' there are stratified sands with a thickness of 55 or 60 feet where best developed near the central part of the heights, following the lower beds conformably and apparently laid down in shallower water but under similar climatic conditions. The lower 4 or 5 feet have clayey layers, but above this the sand is quite coarse, through free from pebbles, and shows cross bedding in some layers. In the sand are found all the usual minerals of Archean rocks, and a few bands of garnet and magnetite occur, evidently arranged under wave action, as on the present beach at the foot of the cliff. Just over the peaty clay there is sometimes an accumulation of coarse woody material, flattened twigs, bits of bark, etc., with quite large

branches of Larix americana and Abies balsamea; and similar layers but in less quantity occur at a few points 20 or 30 feet higher up in cross bedded sand. Near the top of the sand numerous nut-like concretions of brown iron ore are found and occasionally also a few shells, such as Sphaerium rhomboideum, S. fabale, Limnaea sp., Planorbis sp., and Valvata tricarinata, but unios have not been obtained from them. The stratified sands were apparently laid down like the clays, from materials brought from the north by the Laurentian river, but in shallower water where wave action was effective, forming wide sand flats and largely filling the western side of the bay previously described. If they stretched eastwards toward the Pickering shore of the bay they must have been eroded afterwards, since they run out 8 or 9 miles from the river Don. That the stratified sand has undergone great erosion will be shown later. The sand is exposed for about 5 miles along the Scarboro' cliffs and is found overlying the peaty clay 6 miles west near Mt. Pleasant cemetery, so that it extends at least 11 miles.

A series of interglacial sands and gravels occurs in western Toronto and is well exposed in large pits near Christie and Shaw streets; but its exact relationship to the Scarboro' deposits is not certain. Where the two series meet near the corner of Dupont and Bathurst streets there are two or three beds of clay with peaty layers interstratified with sand, suggesting that the sand and gravel are of the same age as the Scarboro' clay. In the sewer opened at this point the only fossils found, beyond the remains of beetles, mosses, seeds, etc., from the peaty layers, are a few small bits of wood, which have not been determined, and the ulna of a mammoth or mastodon. The latter, however, may not belong to these beds, since it has been smoothed and scratched by glacial action, and may have lain on the surface at the time of the Wisconsin ice advance.

In the sand and gravel pits half a mile to the west no clay is to be seen and it is not certain whether the beds correspond to the warm climate period of the Don, or to the cool climate period of Scarboro', or include the equivalents of both periods.

At Mr. Adare's sand pit a considerable number of fossils have been obtained, including numerous campelomas, two or three species of pleurocera, Valvata sincera, two or more species of sphaerium, and fragments of unios, all shells which occur in the Don beds. Beside these fossils bits of elephant tusks and a large atlas vertebra, probably of Bison americanus occur, but none of the species is decisive as to climate, though the mammoth or mastodon suggests a cool climate.

The sand and gravel beds have a thickness of at least 78 feet and rise 130 or 140 feet above Lake Ontario, but their extent is unknown, as they are in general buried under bowlder clay. It is certain that these beds were formed under different conditions from those either of the Don or Scarboro'. They are of coarser and more variable materials, often showing very marked cross bedding, probably produced by currents rather than waves, and sometimes apparent unconformities such as are made by a stream changing its bed. We may suppose that an interglacial Humber river coming in from the west or northwest brought down sand and gravel at the edge of the great bay, mingling them at some points with the clayey delta materials of the Laurentian river.

This brings to a close the series of deposits composing the Toronto Formation. In all there are four varieties, the sands and clays of the Don with their warm climate trees and Mississippi unios; the peaty clays of Scarboro' with their seventy extinct beetles and their small flora, suggesting a cool, but not arctic climate; the stratified sands overlying them, probably forming a continuation of the cool climate period; and the western sands and gravels with elephants, bisons and some shellfish affording little evidence as to climate. The maximum thickness observed in each set of deposits is as follows:

3. Scarboro' sands - -	60 feet.	4. Western sands and gravels, 78 ft.
2. Scarboro' peaty clays	94 "	
1. Don beds - -	41½ "	
	195½	

The greatest thickness measured at one place is at Scarboro'

Heights where 150 feet of cool climate beds overlie 36 feet of warm climate beds, making 186 feet in all. However as the 36 feet of unio sands and clays commence 5 feet below the level of Ontario and its water filled the well sunk there before the bowlder clay was reached, it is certain that the Scarboro' section contains more than 186 feet of interglacial beds, but how much more cannot be told. It is probable also that the upper sands once reached higher than at present, since their surface evidently underwent great erosion before the overlying bowlder clay covered them.

DRAINING OF THE SCARBORO' LAKE

At its highest point the great interglacial lake must have stood more than 150 feet above Ontario, since the upper beds of the cold climate deposits reach 152 feet. Then came a fall in the level, whether sudden or slow is uncertain, though a slow drainage seems more probable. The cause of the original rise of the water was probably the elevation of the lower part of the Laurentian river valley, near the Thousand Islands. If so we may suppose that the rise of the northeastern portion of the continent was slow, as it is at present; and it may not have gone on at a uniform rate, for there seems to have been a halt at 60 feet above the present lake. If the rise was slow the sinking of the barrier at the Thousand Islands at the close of interglacial times was probably equally deliberate. Ultimately the water fell below the present level of Ontario, as shown by the erosion of interglacial valleys in the strata of the Toronto Formation; but whether the lake was completely drained so as to restore the open valley with its great river or was only partially drained is uncertain.

With the lowering of the lake the channels of the rivers must have been rearranged, for the old bay was now largely filled with clay and sand; and in the Scarboro' section there is evidence of the cutting of three valleys through the stratified sand and peaty clay. The one to the east, where the River Rouge and Highland Creek now flow, was cut down below the

present level of lake Ontario for about five miles, probably by the Laurentian river, which seems to have shifted its bed towards the east as the lake level sank, to avoid the thickest part of the previously formed delta. As no peaty clay has been found in the cuttings made by the Rouge and Highland Creek, but only bowlder clay and later stratified clay and sand, this interglacial valley seems to have been extensive.

Walking westward from Highland Creek the slope of the old valley is seen to rise gently, first the peaty clay showing above the water and becoming thicker and thicker, and then the overlying sand showing itself, finally reaching its maximum thickness about four miles from the first appearance of the peaty clay on the lake shore. How much of the valley already existed before the river began its work is unknown, but at least a considerable thickness of the tough peaty clay must have been cut through, for at Rosebank to the east of the old valley it rises 20 or 30 feet above the lake.

Continuing westward along the shore a second much narrower valley still buried under till and unfossiliferous stratified clay is seen at the "Dutch church," as a vertical promontory three miles from the western end of the Scarboro' section has been called. This "fossil" valley was cut through the full thickness of interglacial sand and clay to a level below the present lake, on the shore of which it shows a width of about 1200 feet. At the top of the peaty clay, 90 feet above the lake, its width is about double this; and its sides then slope gently up to the top of the stratified sand with a total width not much short of a mile. The Dutch church valley was apparently made by a comparatively small stream.

It should be mentioned, however, that Professor Albrecht Penck gives another explanation of the downward dip of the bowlder clay at this point, supposing that the promontory is really a mass of till lodged to the south of an old lake cliff of interglacial times. The old cliff has been exposed again on each side of the Dutch church by the action of the present lake, but the tough clay at that point has resisted better and still remains.

According to this view, after the Scarboro' beds were deposited the water sank to a level below that of the present lake and remained there long enough to cut back the mass of delta deposits to about the position of the present cliff. Although the first explanation seems the more simple, the one given by Professor Penck deserves careful consideration. At present there is not evidence enough to settle positively which is correct.

Toward the west of the Scarboro' exposure the stratified sand gradually thins and disappears beneath the bowlder clay and the same is afterwards true of the peaty clay, which sinks below the lake at Victoria park at the east end of Toronto. Here probably another wide valley was cut, though its western shore is not seen distinctly. The upper stretch of the Don Valley, which turns to the east after emptying into Toronto Bay, discloses only till and the overlying unfossiliferous beds in its ravines, though peaty clay rises to 152 feet near Mount Pleasant cemetery toward the west, and to nearly 100 feet at Price's brickyard to the southeast, suggesting an old river valley between, perhaps of an interglacial Don. The form of this valley is not so well worked out, however, as in the case of the other two.

As no interglacial deposits have been found clearly belonging to this later low water stage, there is no evidence as to the climate during the latter part of the interglacial time; but we may suppose that it grew colder until the region was once more covered with an ice sheet, probably corresponding to the Wisconsin till of the states to the southwest.

LATER GLACIAL DEPOSITS

The earlier (Iowan) ice advance found little obstruction in the region of Toronto and passed over leaving only a comparatively thin sheet of bowlder clay, not greatly modifying the general form of the surface; but the later glacial invasion took place under changed conditions. The broad Georgian Bay — Scarboro' Valley through which the Laurentian river had flowed, was now largely blocked with the great interglacial delta deposits, which no doubt stretched as a tongue some miles in length

out into the valley of the present Lake Ontario. The lower part of these deposits consists of very firm stratified clay strengthened by sheets of clay ironstone; but at the eastern end of Scarboro' Heights the clays have been greatly crumpled and contorted, and even large blocks shifted and tilted, by the pressure of the on-coming Wisconsin ice. As the delta seems to have run about southeasterly it lay almost directly athwart the course of the advancing ice, which, after crossing the later valley of the Laurentian river, had to climb over a ridge at least 150 feet in height, and probably considerably higher, before proceeding on its way diagonally across the Ontario Valley. This obstruction, perhaps aided by climatic variations, seems to have kept the ice more or less in check. Meantime the lower end of the Ontario Valley must have been blocked with ice so that the water once more rose assorting the "rock flour" furnished by subglacial streams as gray stratified clays without fossils overlying the uneven surface of bowlder clay covering the series of ridges and valleys left by the interglacial rivers.

The halt at the Scarboro' delta was long and must have included at least three great oscillations of retreat and advance to account for the complex of tills separated by stratified materials now crowning the heights. The first sheet of till is shown for about nine miles continuously at Scarboro' with the shape of a slightly bent bow, touching the lake at each end and with a sharp downward dip at the Dutch church. The latter is, however, less symmetrically placed than in a bow, being only three miles from the west end and six from the east.[1] The hollow of the Dutch church valley was filled with till containing compartively few stones to a level 50 or 60 feet above the present lake, then merging into gray stratified clay which rises to a height of 165 feet, where it is covered with a few feet of much later Iroquois beach gravel. Very similar clays rising to the same height or a little higher are found at brickyards to the north of Toronto. They burn to a gray brick and so are

[1] See diagram, JOUR. GEOL., Vol. III, No. 6, 1895, p. 624.

easily distinguished from the peaty clay which makes red brick.

The highest part of the Scarboro' escarpment, about a mile east of the Dutch church, gives the best section of these complex glacial deposits. At the point where the old Iroquois beach is cut off for a distance by the present lake cliff, there is a face of 270 feet displaying three layers of bowlder clay separated by stratified sand, the whole overlying the stratified fossiliferous sands of the Toronto Formation. A few hundred yards to the east of this the escarpment reaches its highest level, 354 feet above the lake, but the lower part is not so well shown. The upper portion is, however, more complete, since overlying the third till sheet one finds laminated grayish blue or purplish clay followed by evenly bedded fine sand, on which rests a fourth bowlder clay. Putting the two sections together we have the following complete section:

	Feet	
Bowlder clay No. 4 - - - - - -	48–354	203 feet Glacial Complex
Stratified sand overlying stratified clay	36–306	
Bowlder clay No. 2 - - - - - - -	32–270	
Silty sand, the upper layers crumpled	25–238	
Bowlder Clay No. 3 - - - - - - -	9–213	
Cross bedded sand - - - - - - -	29–204	
Bowlder clay No, 1 - - - - - - -	24–175	
Fossiliferous sand - - - - - - -	59–151	151 feet, Toronto Formation
Peaty clay - - - - - - - - -	92– 92	
Lake Ontario - - - - - - - - -	0	

The whole series of tills with the interstratified sand and clay at Scarboro' amounts to 203 feet in thickness and implies a glacially dammed lake reaching more than 300 feet above Ontario. The highest stratified materials in the neighborhood of Toronto occur, however, at the North Toronto waterworks, 360 feet above the lake, where a well showed several beds of clay alternating with sand and gravel, probably equivalent to some of the beds at Scarboro'.

No fossils have been found in the sands or clays of the glacial complex at Scarboro', but a few have been picked up in stratified sand lying between two beds of bowlder clay at the

Metropolitan power house, a mile or two north of Toronto, Amnicola limosa, a Succinea and fragments of another species. These occur at 220 feet above the lake, but the sand containing them runs up to 247 feet and may correspond to the silty sand between till No. 2 and till No. 3 at Scarboro'.

One of the recessions of the ice, perhaps the one just mentioned, appears to have been very extensive, for two thick beds of bowlder clay are found to be separated by stratified materials at numerous points on the lake shore as far east as Newtonville, fifty miles from Toronto. The same relationship is found near the headwaters of the Don, about eight miles north of the city, and also in ravines to the east, but has not been observed to the immediate west; though the stratified clays lying between two layers of till at Dundas and at several points near Niagara Falls may correspond to the same interglacial stage. In that case the ice must have withdrawn eighty miles in a northeasterly direction before advancing again.

During the first recession of the ice the lake was dammed to a level at least 160 feet above the present, for roughly stratified grayish clay with a few small polished and striated stones is found at many points at about this level, filling in hollows of the bowlder clay, as at the Dutch church and Taylor's brickyard. Afterwards, as shown above, the water stood much higher, since stratified materials are found 360 feet above Ontario or 606 feet above the sea, and may have formed part of a large body of water, covering Lake Erie as well as the western end of Ontario. As the whole of these stratified clays and sands were afterwards overridden by the ice and covered with the latest sheet of till they must be looked on as interglacial. The highest bowlder clay has not yet been traced with certainty west or south of the Toronto region, however, since the four sheets of bowlder clay are very much alike and cannot be discriminated when found alone; and there is a possibility that it ends here, and that the water then filling the Ontario basin was continuous with that of some of the successors of Lake Warren. If so, beach lines may have been formed to the west or south of Lake Ontario while

the last till was being spread over the upper interglacial beds here described. Professor Fairchild places the Warren beach south of Lake Ontario at 880 feet, and his next important water level, Lake Dana, at about 700 feet, both far above the highest interglacial stratified sand or clay at Toronto.[1]

CONCLUSIONS

One who studies the complex set of glacial and interglacial beds of the Toronto region is strongly impressed with the length of time demanded for their production. There is no reason to suppose that the withdrawal of the Iowan ice and the drainage of the waters which it dammed were more rapid than the similar series of events following the latest ice sheet. When the Toronto beds began to be formed the water level in the Ontario valley was probably lower than now in Lake Ontario, and some erosion had already taken place in the Don valley and at other points. There had been time for the warm climate plants to return from exile in full force and for forest trees of a most varied kind, though mainly deciduous, to grow and fall on the banks of the rivers. The unios, too, had already migrated north from the Mississippi stronger in species than they are now. All this may imply as long a time after the Iowan ice sheet withdrew as has elapsed since the last ice sheet departed, before the lowest beds of the Toronto Formation were even begun.

Then came the raising of the rocky barrier at the eastern end of the Ontario basin to sixty feet above the present level, and a halt at that level while the upper sands became browned and cemented with limonite. The climate grew cooler and and then ninety-four feet of clay and fifty-five feet of stratified sand were laid down at Scarboro', the eastern barrier rising meantime to 152 feet above the present level.

Then there was a halt in the elevation toward the northeast and at length a reversal of the motion, the northeastern end of the basin being depressed until the great Scarboro' lake was drained to a level probably much lower than that of Ontario at

[1] Bull. Geol. Soc. Am., 1899, p. 31 and p. 56.

present, and river valleys were eroded through 150 or 250 feet of sand and clay and widened so as to have gentle slopes.

It will be observed that the damming of the interglacial waters is held to be due to epeirogenic changes and not to the presence of ice, since it is inconceivable that an ice dam should hold its place at the Thousand Islands during the ages of mild climate required for the growth of the luxuriant Don forests, largely composed of trees that now barely reach the southern edge of Canada.

It is not unfair to assume that the time after the Iowan ice retreated until the commencement of the Toronto Formation was as long as from the retreat of the Wisconsin ice to the present, a time variously estimated at from 7000 to 30,000 years. The raising of the northeastern barrier of the Scarboro' lake to a height at least 150 feet above that of Lake Ontario may also have required thousands of years, if the results of Dr. Gilbert's investigations as to the rate of tilting of the present lake basins furnish the standard. These two stages cover only the first half of the interglacial time, and probably an equal number of thousands of years were required for the depression of the outlet below that of Lake Ontario and the cutting of wide and deep valleys through the Toronto Formation.

To arrive at the total length of the interglacial period it is not extravagant to double or even triple the number of years since the last Ice age, giving estimates of from 14,000 to 60,000 years or more. It will of course be understood that the length of time since Niagara began to cut its gorge can be estimated only vaguely and that the guess at the length of the interglacial period given here is still less certain.

How long a time the later series of bowlder clays and interstratified materials, more than 200 feet thick at Scarboro', required in their formation one can hardly even guess; but one of the glacial retreats amounted probably to more than 50 miles and may alone have demanded centuries of recession and advance.

The time element in the series of events described has been

somewhat strongly insisted on in this paper, since many geologists who have worked only in regions where the Pleistocene deposits are relatively simple in structure and not of great thickness are apt to underrate the importance of interglacial periods, looking on them as short episodes of retreat and advance in the history of a single Ice age. The evidence adduced here points to completely distinct Ice ages, separated by thousands of years of mild climate. It is not improbable that the present time is merely another interglacial period.

An interesting result of the action of rivers and ice is found in the change of relief in the region since the Iowan ice departed. The valley of the Laurentian river, then probably a hundred feet or more below the present level of Lake Ontario, is now replaced by Scarboro' Heights rising 350 feet above the lake and presenting the highest cliffs on its whole shore.

A summary of the best marked stages in the Pleistocene history of the region is given below, special reference being made to climates and water levels. The latter are of course not absolute levels but only relative, since the region as a whole probably underwent important elevations and depressions during Pleistocene times.

STAGES OF TORONTO PLEISTOCENE

1. Retreat of the Iowan ice sheet.
2. Interval of erosion with water probably lower than at present.
3. Don stage, warm climate trees and Mississippi unios, water dammed by differential elevation toward the northeast to 60 feet above the present lake.
4. Scarboro' peaty clays, cold temperate climate, with trees and mosses and 70 species of extinct beetles, formed as delta by Laurentian river in interglacial Scarboro' bay.
5. Scarboro' stratified sand with some trees and freshwater shells of cold temperate climate, delta completed, lake stands 152 feet above the present.
6. Water drawn off by lowering of outlet, subaerial erosion of previous beds, and cutting of river valleys more than 150 feet deep.
7. Advance of Wisconsin ice front raising the water to about 160 feet as shown by stratified interglacial clay, retreat for 50 miles and re-advance, followed by two later retreats and advances, the water finally rising 360 feet above the present lake.
8. Final retreat of ice sheet, followed by water levels of lakes Warren and Iroquois and a brief entry of the Gulf of St. Lawrence into the Ontario basin, which, however remained fresh.

A. P. COLEMAN.

PROBABLE REPRESENTATIVES OF PRE-WISCONSIN TILL IN SOUTHEASTERN MASSACHUSETTS

INTRODUCTION

In the central portion of the country, where the glacial deposits are spread out in a general northward retreating series of sheets, the tills of the various ice invasions have long been differentiated and classified chronologically with a considerable degree of certainty. In New England, however, each of the prominent advances reached nearly or quite to the southern limit of the area. The repeated passage of the ice over the region, and the consequent severe glaciation to which it has been subjected, has served to remove far more thoroughly than in the region further west the evidences of pre-Pleistocene conditions and of early Pleistocene tills. Under such conditions of glaciation, the preservation of remnants of the early tills would be very exceptional, and it is not strange, therefore, that deposits of these early tills have not previously been found.

While severe glaciation is the rule in New England, the action has by no means been of the same severity throughout the area. The area may be divided into three parts: (1) a northern belt characterized by severe and almost universal erosion with correspondingly little deposition; (2) a middle belt with generally moderate, though sometimes locally severe glaciation, but characterized as a whole by a marked deposition of subglacial till as attested by its drumlins; and (3) a southern belt of generally weak erosion, except in the more exposed localities, accompanied by a comparatively slight deposition of till. This southern belt, the northern limit of which in eastern Massachusetts is a few miles south of Boston, is nearly or quite destitute of drumlins, rarely shows any evidences of severe glaciation such as characterizes the northern belt, and is marked by the occurrence of numerous instances of pre-glacially decayed rock surfaces.

It was while engaged in field work on the surface geology of

this southern belt that the writer first encountered exposures of till of a type entirely unlike that ordinarily prevailing over this part of New England. In composition, in color, and in weathering, the till in question was strikingly different from the ordinary buff till of the region, and had the aspect of being much older than the latter. A further study of its character and associations was found to corroborate the differences first noted, and apparently warranted the conclusion that it should be considered as representing the deposits of an ice sheet which certainly antedated the last invasion, and probably marked the earliest of the Pleistocene advances.

The area embracing these tills is located in the eastern and central portions of the Dedham quadrangle of the United States geological survey at a distance of some twenty miles south of the city of Boston. The position of the quadrangle and of the area of the till localities is shown in Fig. 1.

It will be seen from this map that the tills are situated some fifteen to twenty miles inside of the interlobate moraine near Plymouth, and at a distance of some fifty miles north of the line of the corresponding terminal moraine. This moraine, for in origin it is a unit, is usually correlated chronologically with the Wisconsin. If this is so, and there are apparently no grounds for doubting the conclusion, it is evident that the till sheet which covers the surface of this portion of Massachusetts to an average depth of perhaps five to fifteen feet, and which is clearly contemporaneous with the moraine, is likewise of Wisconsin age.

Observations on Massachusetts glacial deposits of an age earlier than those of the last ice advance have been few in number and, with the exception of occasional instances of the burial of stratified drift deposits beneath later tills, have been confined to the vicinity of the moraines along the south coast where the conditions for differentiating the glacial deposits are more favorable than in the inland area to the north.

Before considering the evidences of older tills which the writer believes he has discovered beneath the Wisconsin till sheet, mention will be made of a number of papers presenting

evidences of possible interglacial phenomena or of plural tills in this part of New England.

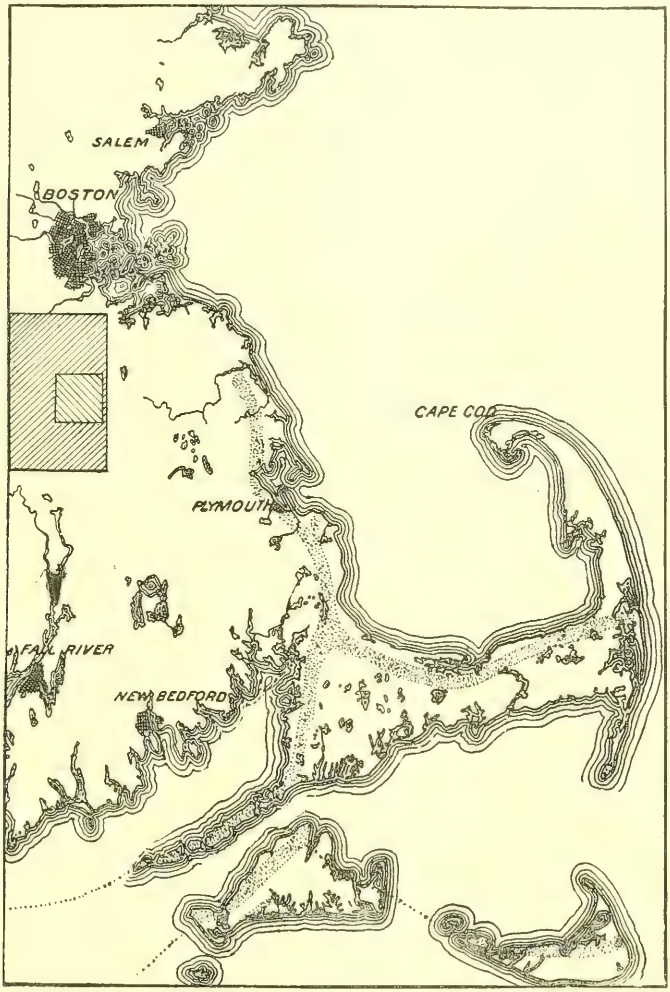


FIG. 1.—Sketch map of southeastern Massachusetts, showing the location of the Dedham quadrangle and of the special map of till localities (Fig. 2).

One of the first papers describing occurrences suggestive of interglacial deposits was that published by W. W. Dodge[1] in

[1] Some Localities of Post-Tertiary and Tertiary Fossils in Massachusetts. Am. Jour. Sci., Series III, Vol. 36, pp. 56, 57.

1888. Though not recognizing the true nature of the material, he described a section of the Great Head Drumlin of Winthrop, a few miles northeast of Boston, and showed that beneath the great mass of clayey material, now known to be till, it possessed a core of fine loose gravel rising several feet above the base of the section (sea level), and containing fossil fragments of Venus mercenaria and other species identical with those existing in the waters of the harbor at the present time.

In 1888, Upham[1] also referred to the presence of the core of modified drift in the drumlin at Great Head, Winthrop, and announced the presence of similar cores in drumlins at Third and Fourth Cliffs at Scituate, some twenty-five miles southeast of Boston. No evidence as to age was brought forth beyond the fact that the stratified deposits were of glacial origin and antedated the ice advance, supposedly the last by which their till coating was deposited.

Shaler[2] was probably the first in Massachusetts to call attention prominently to the occurrence of two distinct tills separated by a long interglacial period. According to him the deposition of the oldest formation of Nantucket, which he describes as a blue pebbly clay till was followed by a long period of submergence and the deposition of fossiliferous marine beds, after which the ice again advanced, partly eroding the marine beds and giving rise to the well-known morainic deposits of the north shore of the island.

In his paper on the "Structure of Drumlins"[3] Upham, in 1899, gave a detailed description of the drumlins of Third and Fourth Cliffs at Scituate and illustrated the descriptions by sections, one of which showed the presence of till both above and beneath the stratified core of the drumlins. The section apparently demonstrated that the stratified deposits were interglacial, at least in the narrow sense of the word, for they were evidently

[1] Marine Shells and Fragments of Shells in the Till near Boston. Boston Soc. Nat. Hist. Proc., Vol. XXIV, pp. 127-132.

[2] The Geology of Nantucket, U. S. Geol. Surv., Bull. 23.

[3] Boston Soc. Nat. Hist., Proc., Vol. XXIV, pp. 228-242.

deposited between an earlier and a later ice advance. The two tills, however, were identical in character, and presented nothing indicative of any considerable time interval between their deposition. The tills and the included stratified drifts are probably to be regarded simply as marking local variations of the same general invasion. Drumlins in which layers of modified drift are inclosed in the till were also mentioned as occurring in other parts of Massachusetts and in New Hampshire and New York.

The descriptions of the drumlins at Scituate were repeated by Upham in 1894 in his paper on the "Madison Type of Drumlins,"[1] but no new facts of importance bearing upon glacial conditions in Massachusetts were presented.

In the table and descriptions accompanying his paper on the clays of Rhode Island and southeastern Massachusetts Woodworth,[2] in 1896, gave three glacial epochs. The first and second were separated by the deposition of the fossiliferous marine gravels, sands, and clays of the Sankaty sub-epoch, as was recognized by Shaler on Nantucket. The second ice invasion, which is apparently assumed (p. 977) as the cause of the strong folding of the Cretaceous, Tertiary, and early Pleistocene strata of Gay Head, etc., and the last invasion are separated by what is designated as the Vineyard interval of extensive subareal erosion, accompanied by deposition below the present sea level.

In the chapter on the clays about Boston, Marbut and Woodworth[3] give reason for believing that the clays were probably of esturine or marine origin, and were deposited in connection with a previous ice invasion. Several sections are described and illustrated which show that the clays are in a number of cases overlain by drumlins which were formed during the last ice advance. The clays frequently present evidences of strong erosion, probably due largely to the action of over-riding ice

[1] Am. Geol., Vol. XIV, pp. 69–83.

[2] The Glacial Brick Clays of Rhode Island and Southeastern Massachusetts: The Geology and Geography of the Clays. U. S. Geol. Surv., Seventeenth Ann. Rept., Pt. I, pp. 975–988.

[3] Loc. cit., pp. 989–998.

(p. 991). According to the evidence presented, the clays are contemporaneous with an earlier ice advance, and are clearly older than the last, but nothing definite as to the length of time intervening is known.

In 1898, Shaler in his paper on "The Geology of the Cape Cod District,"[1] again recognized the existence of two tills, between the deposition of which a period of great length intervened. In this interval he recognized the deposition of three sedimentary formations:[2] the Nashaquitsa, the Barnstable, and the Truro, each of which was followed by prolonged periods of aqueous erosion. This interglacial time was regarded as vastly longer than that which has elapsed since the disappearance of the ice of the last invasion.

DESCRIPTION OF TILL EXPOSURES

The ordinary till exposures in southeastern Massachusetts present the following characteristics. At the top lies a light buff till consisting of the usual heterogeneous mass of clay, sand, and bowlders. The percentage composition of this till varies within wide limits, especially in regard to the quartz-flour and clay constituents which range from a combined amount of perhaps 10 per cent. or less in some of the tills in the southern portion of the state to an average total of some 55 per cent. in the drumlins about Boston.[3] In most sections the till is moderately oxidized from top to bottom, as indicated by its buff color, but where natural or artificial cuts have exposed it to any considerable depth it is found to pass downward into an unoxidized portion of a gray or bluish-gray color, usually designated as blue till. The depth to which the oxidation extends presumably depends somewhat on the percentage of the clay constituent of the till. Though the oxidation is very much less conspicuous in tills high in sand, the depth to which the oxidation extends is probably

[1] U. S. Geol. Surv., Eighteenth Ann. Rept., Pt. II, pp. 497–593.

[2] Loc. cit., pp. 535–538.

[3] W. O. Crosby: Composition of the Till or Bowlder Clay. Boston Soc. Nat. Hist. Proc., Vol. XXV, p. 25.

greater than in the more clayey tills. In the Boston drumlins, which are high in clay, the oxidation has usually reached a depth of some twenty feet. Where the bedrock upon which the tills rest is exposed to view it is ordinarily found to present well glaciated surfaces, showing no traces of decomposition beyond a thin superficial zone seldom more than half an inch in thickness, and often represented only by a slight surface discoloration.

CENTER STREET EXPOSURE, BROCKTON

In marked contrast to the section just described are the sections exhibited by the older tills observed by the writer. The first of these old tills to be observed was exposed several years ago during excavations for the foundations of one of the heavy stone arch bridges which were necessitated by the abolishment of the grade crossings of the New York, New Haven and Hartford Railroad. (Fig. 2, Exposure 1.) The first six feet or so from the surface was of the ordinary slightly oxidized buff till of the last, or Wisconsin invasion, but on going deeper, instead of becoming lighter and gradually merging into the unoxidized blue till as in the ordinary typical section, the buff till gave place abruptly to a mass of distinctly red and yellow till. This till at the time it was seen by the writer was exposed to a depth of about four feet, but was later excavated to a depth of from two to four feet more, at which point it was found to rest on a deeply decomposed and highly oxidized conglomerate of Carboniferous age. Besides its high colors, due to the advanced state of oxidation, the lower till was found to differ in a marked degree in composition from the ordinary buff till. Clay, including quartz-flour, which in the overlying till forms less than one half of its bulk, constitutes nearly the whole of the lower till. The pebbles of the upper till comprise some 25 per cent. or more of its mass and are varied in type, complex in composition, fresh in appearance, and have often been transported considerable distances. In the lower till, on the other hand, the pebble component probably never exceeds 10 per cent. of the mass, and only the resistant quartz and quartzite pebbles from the underlying

rock are usually represented. The buff till is without visible structure, while the lower oxidized till is characterized by a distinct, but rude and highly irregular lamination.

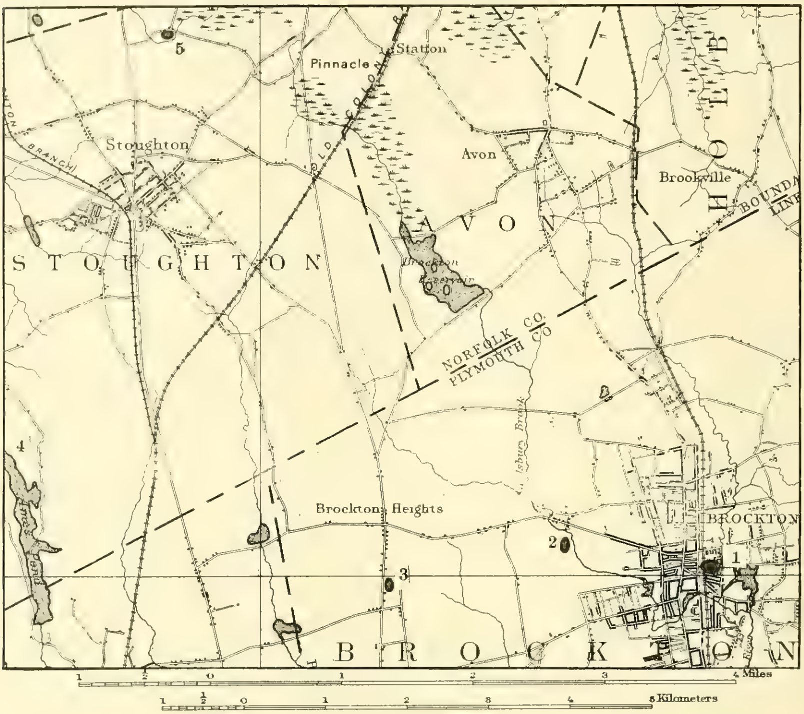


FIG. 2.—Map[1] showing location of exposures of tills of probable Pre-Wisconsin age. 1. Center street exposure, Brockton; 2. Intervale Park exposure, Brockton; 3. Pearl street exposure, Brockton; 4. Ames pond exposure, Stoughton; 5. Pine street exposure, Stoughton.

The derivation of the lower till from the underlying decomposed conglomerate is plainly indicated by its color and composition. This conglomerate is composed largely of pebbles of granite, black slate, quartzite, and some quartz,[2] embedded in a

[1] Reproduced from special edition of the Dedham quadrangle of the U. S. Geological Survey. Presented through the courtesy of Professor W. O. Crosby and the Boston Society of Natural History.

[2] Quartz also occurs in considerable amounts in the numerous small veins cutting the conglomerate.

somewhat feldspathic sandy matrix. It exhibits a rather perfect cleavage at right angles to its stratification. Where so situated as to be exposed to the full action of the ice at the time of the last invasion, it exhibits smooth, hard, and well glaciated surfaces of a dark gray color with almost no evidences even of superficial oxidation. In less exposed positions, such as exist along the well defined valley running southward through the city of Brockton just east of the center, the glaciation was apparently exceedingly slight. It is in such positions that the decayed conglomerate from which the lower till was derived is found. At the surface the conglomerate presents the high colors of advanced oxidation, but somewhat irregularly arranged owing to variations of the original composition of the rock. Some of the portions free from iron give on decay spots or streaks of an almost white sandy clay. The predominating color is a distinct yellow, interspersed with red in many places. The rock is so soft at the surface that it can sometimes be removed by pick and shovel. The depth of the extreme decay is somewhat variable, possibly averaging from two to three feet, though it is probably considerably greater in places. From the highly decayed portions, the rock passes downward by insensible gradations into less altered portions, but in none of the shallow excavations which the writer has seen has fresh rock, such as is exposed where the glaciation has been severe, been reached. The decomposed conglomerate probably underlies most of the low region near the center of the city and has been exposed in the laying of water pipes, drains, sewers, etc., along Center and Crescent streets and near the high-school building on Main street. Many of the excavations in which decomposed conglomerate was exposed were made ten or more years ago, and though the presence of the decayed rock can be vouched for, the writer cannot say with certainty that it was everywhere overlaid by the oxidized till, though later observations suggest that such was probably the case.

It is certain that the deep rock decay antedates the last ice invasion. If this decay is the result of pre-Pleistocene weathering,

the evidence naturally leads to the conclusion that the overlying oxidized till evidently derived from it was the result of the re-working of the soft decomposed material by the first ice advance, in which case it is probable that it should be correlated with the Kansan or pre-Kansan glacial deposits of the central portion of the country. If, on the other hand, the rock decay is considered as of interglacial origin it constitutes of itself an evidence of a long interglacial period. This last supposition, however, cannot be maintained, for the rock weathering is far too extensive, reaching downward as it does to a depth of some feet, to have been brought about in interglacial times.

An alternative supposition which naturally suggests itself is that the oxidized till may after all be considered as of Wisconsin age, and as representing the re-working of the pre-Pleistocene decomposed rock material which had somehow been preserved from the erosive action of the earlier invasions. In answer to this it may be urged that, while the actual erosive power of the earlier advance was comparatively slight, it is almost impossible to conceive of an ice sheet so weak that at a point more than fifty miles from its margin it passed over soft decomposed rock material without re-working it in any degree, especially as till deposits of the corresponding advance occur along the outer margin at Nantucket sixty miles further south. A further and apparently fatal objection to the consideration of the oxidized till as of Wisconsin age lies in the fact that, in the re-working of the previously decayed rock and soil by a sheet known to be specially characterized by numerous foreign fragments, there would at least be a gradual transition between the highly oxidized and the ordinary type of till. In reality, however, the contact is so sharp that the breadth of a hand will usually, and sometimes more than cover it.

INTERVALE PARK EXPOSURE, BROCKTON

At the time of the laying out and leveling of the tract of land known as Intervale Park, about a mile west of the Center street locality, a number of good sections of till were transiently

exposed. One of these sections (Fig. 2, Exposure 2) showed a yellow and red oxidized till, almost identical in appearance with the one previously described and lying in a corresponding position beneath the ordinary buff till. The general character of the exposure is shown in Fig. 3, in which the horizontal and vertical scales are the same.

In composition the lower till was similar to that of the Center street exposure, being probably as high as 70 or 80 per cent. in clay and quartz flour. Like the first, it was evidently derived from the underlying conglomerate and showed the same quartzite pebbles and the same yellow and red colors. The prevailing

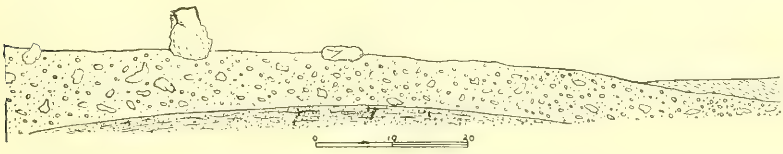


FIG. 3.— Section showing the relations of the older and younger tills in the Intervale Park exposure, Brockton. (Exposure 2 of Fig. 2.)

color, however, was somewhat lighter, yellow and gray predominating. Like the Center street exposure it was irregularly laminated and separated from the overlying till by a sharp and distinct line of demarcation.

With a view to comparing with other tills, samples of the oxidized till were collected and examined as to their composition. In the following table the results of the examination are given and compared with the immediately overlying till, and with the till of drumlins in the vicinity of Boston:

	Bowlders and gravel	Sand and quartz flour	Clay
1. Highly oxidized clay-till [1] - - - - -	10	68	21-23
2. Ordinary till overlying the above [2] - -	50	45	5
3. Clay-till of Boston drumlins [3] - . - -	25	63	12

Attention is especially called to the clay constituent which in the lower till is about four and a half times as great as in the

[1] Clay determined chemically, others estimated from physical examination.

[2] Estimated from physical examination.

[3] Average of sixteen careful physical analyses by W. O. CROSBY, Boston Soc. Nat. Hist., Proc., Vol. XXV., p. 124.

overlying till and nearly twice that of the tills of the drumlins, which represent the most clayey tills previously known. The difference in the amount and character of the included rock material is also very marked. The lower till was found to contain only about 10 per cent. of pebbles, mainly under an inch in diameter and consisting principally of quartzite. The upper till contained some 50 per cent. of pebbles and cobbles, besides a large number of massive bowlders of granite and diorite varying from five to ten or even twenty feet in diameter.

The underlying rock was not exposed in the immediate vicinity of the till here described, but it is known to be a conglomerate similar in character to that of the Center street locality, and to be likewise considerably decomposed.

The great dissimilarity of the lower till from the overlying till, the sharp line of demarcation between the two, the evident derivation of the former from deeply decomposed conglomerate, and the exceptionally close resemblance of the lower till to that of the Center street exposure, have led the writer to correlate it with the latter and to refer it to the same early Pleistocene invasion.

PEARL STREET EXPOSURE, BROCKTON HEIGHTS

The writer's attention was called to this exposure of what may probably be considered as a representative of pre-Wisconsin till by Mr. M. S. W. Jefferson, of Brockton, to whom the credit of the discovery of the locality is due. The exposure was within a gravel pit of some size on the south side of Pearl street, a short distance north of its junction with Rockland street (Fig. 2, Exposure 3).

The height of the section was about five feet, of which the upper two feet was of the ordinary type of buff till containing numerous bowlders. The lower three feet was of an entirely different and somewhat remarkable character, being composed of an arkose-like mass of disintegrated material evidently derived from the coarse porphyritic granite which is known to underlie it. At first sight it bears a slight resemblance to a granite disintegrated *in situ*, but a closer examination reveals the presence

of sand and pebbles of foreign material, showing that it is to be regarded as a true till in which, as in the two tills already described, the material is almost entirely derived from the underlying rock. The color of the mass is a dirty, somewhat rusty brown, there being no trace of the higher colors exhibited by the tills previously considered. The line of demarcation between the two tills is much less sharp than in the preceding instances and is due to the predominance of the same granitic material in both tills. The chief difference is that in the lower till the granite is present as a disintegrated arkose-like mass, while in the

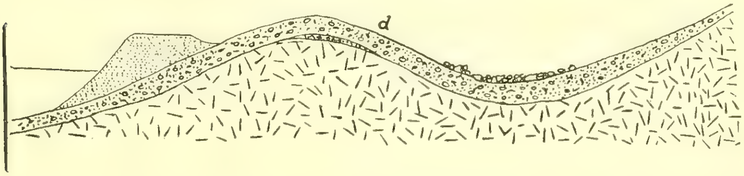


FIG. 4.— Section showing general relations of granite, till, and drift terrace at the Ames Pond exposure, Stoughton. Vertical scale, about 200 feet to an inch; horizontal scale, about 50 feet to an inch.

upper till it occurs in a fresh condition and largely as glaciated pebbles or bowlders.

AMES POND EXPOSURE, STOUGHTON

This exposure is in a gravel pit on the east side of the pond north of the small bay which comes up to the highway (Fig. 2, Exposure 4). The general section of the locality is shown in Fig. 4. The till to be described is exposed on the east slope of the rock and till ridge at *d*.

The lower till is somewhat similar to that in the Pearl street exposure at Brockton Heights, the material being a pink granite. The chief point of difference, perhaps, lies in the fact that the till of the Ames Pond exposure appears to have been originally a bowldery till, the fragments of which in most cases have subsequently completely disintegrated. The disintegrated granitic material probably constitutes ninety or ninety-five per cent. of the mass, and is apparently of local origin since a knob of similar granite projects through the till a short distance to

the north. There are a few pebbles of a fresher, though still distinctly weathered granite dispersed sparingly in the till. The difference in the extent of the decay is probably to be explained by the fact that the process which subsequently brought about disintegration were, in the larger portion of the material, well under way at the time of the ice advance, though actual disintegration may not have taken place until long afterwards. The fresher fragments were probably derived from portions of the ledges from which the more highly decomposed material had previously been removed. The thickness of the lower till as exposed in the gravel pit is about four or five feet. The color of the till is slightly darker than the overlying buff till, but the distinction is not marked.

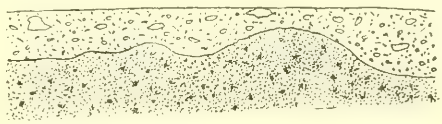
The upper till is composed of a heterogenous mass of material in which the same pink granite predominates, but with a considerable intermixture of foreign material. Its line of demarcation from the lower till is well defined, but, as would be expected from the fact that granite is the predominating material in both cases, is not so sharp as in the first two of the Brockton tills. All fragments of the upper till are fresh and usually present well glaciated surfaces.

PINE STREET EXPOSURE, STOUGHTON

The gravel pit in which was found the last of the tills to be described is located on the south side of Pine street at its junction with Pleasant street near the northern boundary of the town (Fig. 2, Exposure 5). The cut was about fifteen feet deep at the time it was seen by the writer. Two tills were distinctly exposed in the section, the relations of which are shown in Fig. 5.

The lower till, as in every case which has been described, is very homogeneous in composition. In this instance it is composed largely of the disintegrated material of a biotitic and hornblendic syenite, the source of which is probably close at hand. There is a slight admixture of foreign material but probably not more than 5 per cent. As in the case of the Ames

Pond exposure the till appears to have been originally composed largely of bowlders, the decay of which was well under way at the time of the laying down of the till, but which did not completely disintegrate until some time afterwards. Some of the larger bowlders still show undecomposed cores, but as a rule the disintegration is complete. The color is rather a dark brown, somewhat similar to the reddish-brown color of decomposed diabase, and serves to sharply separate the lower from the upper till.



Vertical and horizontal scale: 1 in. = 30 ft.

FIG. 5.— Section showing the relations of the older and younger tills in the Pine street exposure, Stoughton. (Exposure 5 of Fig. 2.)

The upper till is of the ordinary heterogeneous type abounding in foreign fragments, many of them rather far-traveled. There is proportionally little of the dark syenite in the upper till, differing in this respect from the Pearl street and Ames Pond exposures in which the predominating material of both tills is the same. When present in the upper till the syenite is fresh.

In the case of the Center street and Intervale Park exposures of Brockton the reasons have been given for regarding the tills as probably representing the earliest of the Pleistocene advances. One of the most prominent of these reasons, namely, the position of the till upon deeply decayed and unglaciated rock surfaces, cannot be applied with certainty to the last three tills described, since the immediately underlying rock is not exposed and its condition is not known. The difference in the colors is also a noticeable feature, the granite and syenite tills showing nothing of the high colors which characterize the tills derived from the conglomerate. A study of granites decayed *in situ*, however, shows that high colors are not the necessary accompaniment of disintegration such as the granite of the tills has undergone. The same close dependence of composition upon the underlying or immediately adjacent rock, the same small percentage of foreign material, the same highly weathered

character, and the same distinct or even sharp division from the overlying tills, all seem to point to an origin similar, and probably contemporaneous with that of the Brockton tills. The deposition of the tills is believed to date from the time of earliest Pleistocene ice advance.

POSSIBLE INTERGLACIAL ROCK DISINTEGRATION

A further reason for considering the tills composed of highly oxidized or disintegrated material as representing the first ice invasion lies in the fact that the weathering is distinctly more advanced than in the exposures of what seems likely to prove to be examples of interglacial weathering. It has been seen that at the advent of the first ice sheet the rocks of the region were deeply decomposed as, for example, the conglomerate at Brockton. It is also known that where the conglomerate was so situated as to receive full benefit of the erosive action of the ice of the last advance the ledges are perfectly fresh. Between these two extremes there are numerous examples of a partial breaking up of the ledges by atmospheric agencies, and a partial disintegration. Such a case is illustrated in Fig. 6.

The moderate amount of decay exhibited by ledges of this class, as compared with ledges known to be pre-glacially decomposed, or with tills formed from such decomposed material, and the considerable amount which they show as compared with the freshly glaciated ledges of the last ice advance, seem to make a plausible case in favor of the view of interglacial weathering. In this case we have a rough measure of the time from the earliest of the Pleistocene ice advances to the present time, for both the field relations and weathered character show that the conditions mainly antedate the last of the ice invasions. The evidence of this weathering, if it be accepted as interglacial, is indicative of the great length of such time as compared with that which has elapsed since the final disappearance of the ice.

The preservation of these ledges evidently depended in many cases upon the character of the topography, but this is not always the case. The general explanation probably lies in the

fact that all of the occurrences noted lie in the southern belt, in which, with the exception of the hills and other prominences, the work of the ice of the last invasion was largely one of deposition.

FIG. 6.—View of disintegrated ledge of conglomerate, Intervale Park, Brockton. The weathering is supposed to be interglacial in age.

SUMMARY AND CONCLUSIONS

1. The Pleistocene ice sheet on its first advance found a somewhat deeply decayed rock surface, many remnants of which are now to be seen.

2. The erosive power of the first advance was not sufficient to entirely remove the products of decay, for tills evidently composed of such products have been found by the writer beneath the ordinary tills of the region. These have been described in this paper.

3. The older tills are probably the result of the re-working of

pre-glacially decomposed rock and its accompanying soil, rather than by the process of accretion, by which many of the later deposits of till, such as drumlins, etc., were built up.

4. The remnants of the early till are characterized by (*a*) the presence of 20 per cent. or more of clay, (*b*) the presence in some of the tills of 10 per cent. or less of pebbles, (*c*) a composition which is dependent almost entirely upon the underlying or immediately adjacent rock, (*d*) the decayed or disintegrated character of its materials, (*e*) the presence of colors characteristic of high oxidation, (*f*) its position in certain cases upon deeply altered and practically unglaciated rock surfaces, and (*g*) its distinct line of demarcation, both as to color and composition, from the overlying till.

5. The upper till, on the other hand, is characterized in the region under discussion by (*a*) the presence of probably less than 5 per cent. of clay, (*b*) the presence of 40 to 50 per cent. of rock fragments, (*c*) a composition often largely independent of the immediately underlying rock and including numerous far-traveling erratics, (*d*) slight oxidation, and (*e*) by its unweathered and distinctly glaciated fragments.

6. No evidences of a soil zone between the two tills have so far been observed.

7. It seems probable that there were comparatively few localities in which the highly oxidized tills remained at the time of the last invasion, for otherwise there should be more traces of oxidized material, especially the colored clays, in the later till. The early tills were probably largely eroded during the later stages of the same ice sheet by which they were formed.

8. The action of the ice of the last advance in many cases was to cover the earlier till remnants by a new coating of till, and was protective rather than erosive in its nature.

9. Nothing indicative of more than two general periods of glaciation has been noted by the writer. The position of stratified deposits between two tills identical in character, and of the Wisconsin type, is probably to be explained as resulting from

the overriding of deposits laid down during a temporary retreat or local recession of the ice of the same general invasion.

10. The post-glacial weathering is in general confined to a slight oxidation of the till, the wearing of the pebbles, bowlders, and glaciated ledges being usually limited to a slight superficial decay or a mere discoloration of the surface.

11. There are numerous exposures showing rock disintegration of a type intermediate between the high decay characteristic of the pre-Pleistocene weathering and the slight weathering of post-glacial times. This disintegration is believed to have taken place largely in interglacial times.

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SKETCH OF THE GEOLOGY OF THE SALINAS VALLEY, CALIFORNIA[1]

In June and July 1900, under the direction of Dr. J. C. Branner, Mr. L. D. Mills and the writer undertook to trace out and map the formations in Monterey county, California, which appear to bear directly on the underground water supply of the Salinas Valley. During this and two subsequent trips to the same region the data were collected which form the basis of the present paper.

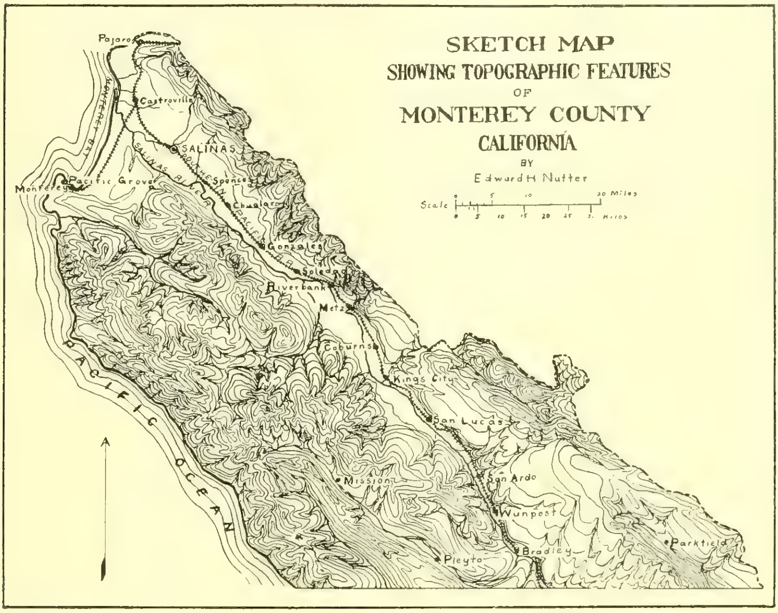
The Salinas Valley is a long, sword-shaped depression extending nearly southeast from Monterey Bay, to and across the southern end of Monterey county. The larger tributaries of the Salinas River run for a good part of their length in troughs parallel to the main valley, forming with it part of a remarkable series of valleys existing in the Coast Ranges of California, which for a distance of nearly five hundred miles are almost exactly parallel. In the Salinas Valley are evidences of a fault in the older rocks extending very persistently for several miles parallel to the main valley.

In its northern part, if not throughout its whole length, the Salinas Valley is cut in granite and other crystalline rocks, principal among which are biotite schists with crystalline limestone lying unconformably on them. The granite is intruded into the schists and is apparently the agent which metamorphosed the limestone. The granites, gneisses, and schists cover large areas while the limestone occurs only in patches. Of the crystalline rocks other than those mentioned there is one area of an eruptive that looks like andesite on top of the water-shed between Monterey and San Benito counties, northeast of the town of Salinas, and an area in the neighborhood of Metz containing a variety of intrusive and eruptive rocks in addition to several kinds of metamorphics. Hand specimens of these have been collected

[1] Published by permission of the director of the U. S. Geological Survey.

but have not yet been identified. There is also an extensive area of serpentine along the southeastern boundary of Monterey county.

Since it was cut out the Salinas Valley has been filled with sediments of Tertiary and later age. If there are sediments older than the Miocene and newer than the metamorphics, they

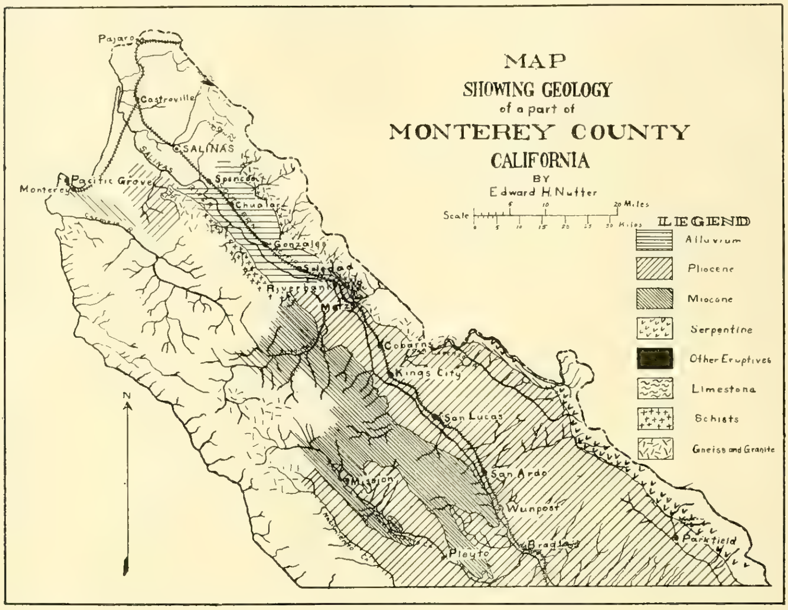


are not uncovered at any place visited, with the exception perhaps of a small area about the headwaters of the San Lorenzo River near the county line, where there are rocks resembling the Franciscan cherts. The Tertiary rocks are of Pliocene and Miocene ages, and these are separated by an unconformity.

Southeast from the town of Salinas the valley narrows down from a broad rolling plain to a sloping floor about eight miles wide, bounded on each side by granite mountains. Southwest of Salinas, across the river, are highlands formed of Pliocene[1] sands and gravels, and deeply scored by ravines.

[1] The age of these beds was determined by Mr. Ralph Arnold, of Stanford University, from fossils collected by the writer fourteen miles east of Monterey, in the center of section 20, 16 south, 3 east.

From Spence's to a few miles southeast of Soledad the floor of the valley is covered by material washed in from the granite hills and mountains on either side. This alluvium or granite wash is very porous, and this has given rise to topographic features characteristic to this part of the valley. In the rainy season the water rushes out of the steep canyons bearing a heavy burden



of sediments until it reaches the floor of the valley, where it sinks, leaving sand, gravel, mud and drift strewn around over the place where it disappeared. This has gone on until alluvial cones have been built up several miles wide and of considerable thickness. These alluvial cones or fans have themselves been cut by smaller gulches having steep sides and flat bottoms. A rudely stratified earthy conglomerate, the pebbles of which are angular fragments of granite, schist and gneiss, varying in size from sand grains to pieces the size of one's head, is usually found capping these fans.

It seems probable that both Pliocene and Miocene sediments underlie the alluvium, for they occur at the northwestern end of

this area and dip under it at the southeastern end below Soledad. In addition to this, there is a point of granite projecting through one of the alluvial fans about two and one half miles east of Gonzales in 16 south, 3 east, section 14, southeast quarter. The top of this granite exposure is capped with shale that has all the appearance of the diatomaceous Miocene shale. It seems probable that the structure of this region is that shown in the accompanying section (Fig. 1).

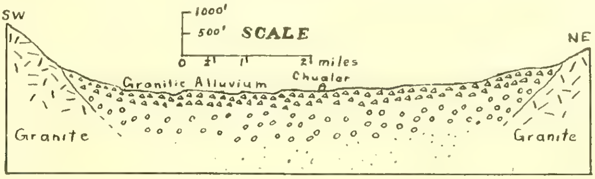


FIG. 1.—Ideal section across the Salinas Valley showing its probable structure at Chualar.

Beginning near Riverbank on the east, and at a point about six miles southwest of Soledad, on the west, water-worn gravels of Pliocene age begin to crop out from beneath the granitic talus, and gradually rise and form a terrace that extends eastward for about eighteen miles from Kings City to a series of anticlinal valleys which form the eastern boundary of the terrace or plateau.

Serpentine is abundant along the eastern edge of the terrace, though whether or not it forms a continuous sheet as indicated by the accompanying sketch map is not now known, for the parting was not followed continuously, but was visited only at such places as the roads permitted. At these points serpentine was found underlying the Pliocene plateau. The edge of contact between the Pliocene beds and the underlying serpentines

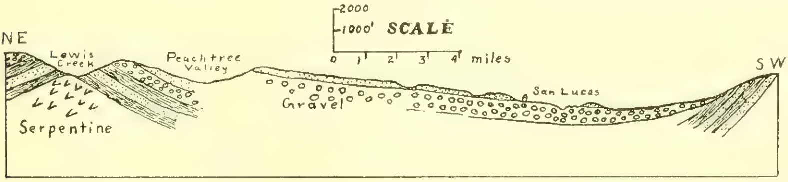


FIG. 2.—Structure of the Salinas Valley and adjoining plateau along a northeast-southwest line through San Lucas.

reaches an elevation of nearly two thousand feet above Kings City from near Parkfield northwest to a point fifteen miles east of Kings City.

The structure of the country between Kings City and the alluvium covered district is shown by (Fig. 3) a section through Metz.

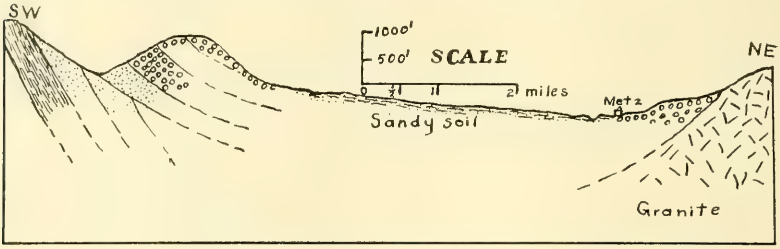


FIG. 3.—Structure of the Salinas Valley along a northeast-southwest line through Metz.

From Kings City to the San Luis Obispo county line the Pliocene beds form the eastern escarpment of the immediate valley with an average height of about one hundred feet above the river. The lower beds extend entirely under the valley, thereby making the terrace area or plateau tributary to its underground water supply.

For the most part the Pliocene beds overlie the Miocene, but in some places they lie directly on the older rocks (Fig. 4).

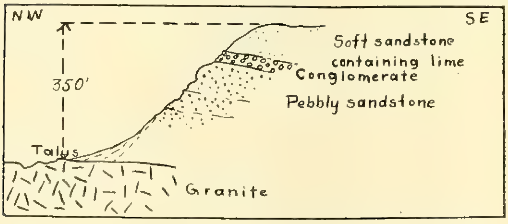


FIG. 4.—Croppings of terrace beds five miles northeast of Kings City at the head of the Salinas Valley Water Company's ditch, on the San Lorenzo River.

In the southern part of Monterey county there have been at least two elevations of the land since the deposition of the Miocene beds, for the Pliocene gravels forming the large plateau are to a great extent composed of shale pebbles, and these same pebble beds have been tilted along with the underlying beds of shale. In places the Pliocene and Miocene may be conformable.

This seemed to be the case near the southernmost point of the Miocene area shown on the accompanying geological sketch map. Here the gravels and sands rest on the sandstones and shales and have apparently the same dip and strike. For the most part, however, along the parting between the Pliocene and the Miocene, there is such a marked difference in the dip of the two series on either side of the contact, as to make almost certain an erosion line between them.

The Miocene shales and sandstones are much contorted, and

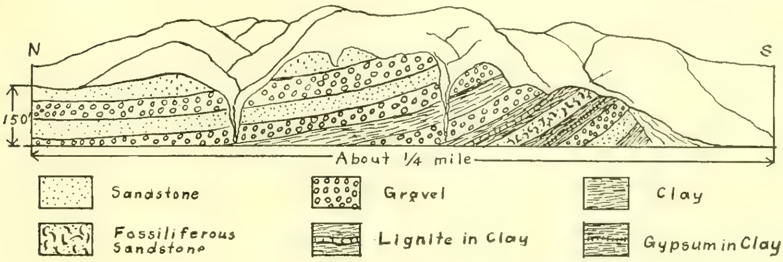


FIG. 5.—Terrace beds exposed in a railway cut three miles northwest of Bradley.

are characterized by steep dips, sometimes vertical. The Pliocene sands and gravels[1] have much gentler dips and are also persistently characterized by having a capping of soft limy sandstone.

The ranges of hills lying between the Nacimiento and San Antonio creeks, and the San Antonio Creek and the Salinas River are made up almost entirely of Miocene sandstones and shales; while the valleys of the Nacimiento and San Antonio are filled with the Pliocene sands and gravels.

There is much granite and gneiss in the region drained by the head waters of the Arroyo Seco, the San Antonio, and the Nacimiento, as the beds of these streams are filled with pebbles and bowlders made up of these rocks.

[1] The age of this Pliocene area was determined by fossils collected in a railway cut three miles northwest of Bradley. The Miocene fossils are from shale beds outcropping on the southwest bank of the Salinas River at Wunpost. They were all identified by Mr. Ralph Arnold.

RECAPITULATION

The Salinas Valley in Monterey county is a trough that probably holds a great deal of water. In its northern part from near Riverbank to some point between Chualar and Salinas it is covered with talus washed in from the mountains.

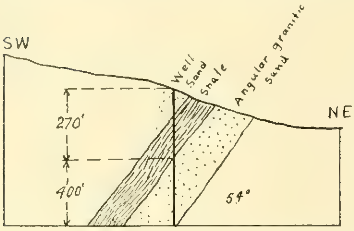


FIG. 6.— Sand and shale beds at Barrett's oil well, four miles northwest of Parkfield. Water was encountered at two levels in the angular granitic sand. The elevation of the mouth of the well is 1800 feet above Kings City.

Pliocene and Miocene sediments underlie this talus though to what extent is uncertain. Going southward the Pliocene beds rise from beneath the talus at about Riverbank; and from east of Kings City, to the southward, they form an extensive plateau which continues into San Luis Obispo county and is probably tributary to the underground water supply of the Salinas Valley.

In the drainage area of the San Antonio and Nacimiento creeks there are also Pliocene gravels which are indirectly tributary to the underground water supply of the Salinas Valley.

It seems probable that deep wells put down near the western margin of the Pliocene terrace between San Lucas and the San Luis Obispo county line may yield considerable water, perhaps artesian.

Slightly salty water has been found in wells in the terrace beds above the valley, though there are folds lying between these bore holes and the valley (Fig. 6).

It is possible that artesian water may be found in the region of the San Antonio and Nacimiento creeks, but not enough detailed work has been done there to warrant any definite con clusions upon the subject at present.

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NOTES ON THE FOSSILS FROM THE KANSAS-OKLAHOMA RED-BEDS

THE age of the series of rocks lying conformably on the Permian and unconformably below the Comanche Cretaceous in Kansas and Oklahoma has for a number of years been considered problematic. The earlier Kansas geologists classified these formations anywhere between the Carboniferous and the Middle Cretaceous. Later investigators have agreed that the series is not older than the Permian, nor more recent than the Jurassic. In Texas, rocks which appear to be of the same age are assigned to the Permian on the authority of such paleontologists as Cope and White.[1]

In the absence of certain determination as to age, the general term Red-beds has been applied to these formations in Kansas and Oklahoma. The term refers to the lithological appearance of the rocks. Blood red sandstones, clays, and shales make up the greater part of the thickness of the series. The shales are frequently strongly impregnated with mineral salts, of which gypsum and common salt form the larger part, although borax, magnesia, and others are not infrequent. These salts impart to the water of a great part of the area a characteristic taste, often rendering it unfit for use. In the central part of the Red-beds areas several ledges of massive gypsum occur. These ledges outcropping to the east form the escarpments and caps of the noted Gypsum hills which extend south from southern Kansas to the Wichita Mountains, and thence into central Texas. Ledges of dolomite and highly saliferous shales are found in many horizons of the Red-beds.

There is not lacking literature on the Red-beds. Some of the most noted geologists and paleontologists of America have written concerning these rocks. Such men as Cope, Hill, Williston, Haworth, Hay, Vaughan, Ward, Beede, Stevenson, and others

[1] Second Annual Report Geological Survey of Texas, 1890, pp. 415–419.

have contributed to our knowledge of the subject. The most comprehensive articles, however, are by Prosser and Cragin. Professor Cragin, in addition to incidental mention of the Red-beds in numerous papers on the geology of southern Kansas, has written two articles dealing exclusively with these series of rocks. In the first paper, entitled "The Permian Series in Kansas,"[1] the Red-beds are classified as Upper Permian, and are included under the Cimarron series, which is divided into two divisions, the Salt Fork and Kiger. Each of these divisions is further subdivided on purely lithological grounds into five formations. Professor Cragin's second paper, "Observations on the Cimarron Series,"[2] is little more than a revision of the former one. The grouping of formations and sub-formations is slightly changed, and a few new points added. These two papers contain the best description of the Red-beds extant. Professor Prosser's paper on "The Cimarron Series, or the Red-Beds,"[3] contains the best historical review of the literature of the subject so far published, as well as an excellent description of the Kansas Red-beds.

The reasons for assigning the Kansas-Oklahoma Red-beds to the Permian were chiefly two, viz., first, these rocks were considered to be of the same age as the Texas Red-beds, which are recognized as Permian; and, second, the series grades conformably upward from rocks of undoubted Permian age. The fact that so far as known not a single fossil has been found in the Kansas Red-beds has always been the great obstacle to the accurate correlation of the series. During the past two years, however, as the result of both private investigation and of the work of the Oklahoma geological survey at least four localities have been discovered in the Oklahoma Red-beds from which fossils have been identified. These localities, with the character of the fossils contained in them, are as follows:

1. McCann's quarry, five miles southeast of Nardin, Kay county; vertebrates, invertebrates, and leaves.

[1] Colorado College Studies, March 1896, Vol. VI, pp. 1–48.

[2] American Geologist, May 1897, Vol. XIX, No. 5, pp. 351–363.

[3] University Geological Survey of Kansas, 1897, Vol. II, pp. 75–95.

2. Two miles northeast of Orlando, numerous vertebrates.

3. Cedar Hill and Bitter Creek, northeast of Watonga; invertebrates.

4. Whitehorse Spring, sixteen miles west of Alva; numerous invertebrates.

Of these localities those numbered 1 and 2 are from the lower part of the Red-beds, not far from the base of the Harper sandstone. The fossils from locality numbered 3 were taken from ledges of sandy dolomite immediately beneath the heavy ledges of gypsum found near the middle of the Red-beds. Locality numbered 4 is from the Red Bluff sandstone in the upper part of the series.

A large vertebrate from McCann's quarry, or locality 1, was identified by Dr. S. W. Williston as *Eryops megacephalous* Cope, a form characteristic of the Permian of Texas. The invertebrates from the same locality were sent to T. Rupert Jones, who classified them as *Estheria minuta*, a Triassic form. The plants were shown to Dr. Lester F. Ward, who said that the forms seemed to resemble Mesozoic rather than Paleozoic types. From the Orlando locality Dr. Williston has identified the following forms: *Diplocaulus magnicornis* Cope; *Diadectidæ* Gen. indt.; *Pariotichus incisivorus* (?) Cope; *Labyrinthodont;* and *Trimerorhachis;* all of which he recognizes as Permian forms. From the locality numbered 3 but one species has been found. This is an invertebrate which here occurs in great numbers, and has been referred by Dr. J. W. Beede with some doubt to the Permian form *Sedgwickia*. The Whitehorse locality has yielded some twenty species of invertebrates, several of which are of new forms.

This locality is from the upper part of the Red-beds, or to be more exact from Cragin's Red Bluff sandstone perhaps 150 feet above the Medicine Lodge gypsum. The following genera are represented: *Conocardium*, *Aviculopecten*, *Schizodus*, *Pleurophorus*, *Bakevalia*, *Naticipsis*, *Pleurotomaria*, *Orthonema* and *Murchisonia*. One form that was at first thought to be *Jagmayeria*, a shell of Triassic age, has since been identified as *Dielasma*, very

like *D. biplex* described by Waagen from the Permo-Carboniferous of India.

Unfortunately no Cephalapods have as yet been found in the locality and until this is done the question of the exact age of the beds may scarcely be decided. The facts at command lead to the inference that the Whitehorse Springs locality is well up toward the close of the Paleozoic

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ILLUSTRATED NOTE ON A MINIATURE OVERTHRUST FAULT AND ANTICLINE

THE figure below represents a miniature anticline passing into a reversed fault above. It is on the Ozark-St. Paul road, on the east side of the road, one mile north of the town of Ozark, Ark. The rocks are of the Coal-measure series, and consist of shale interbedded with thin layers of sandstone. The strike of the fold is about east and west, it being one of the series of feeble folds on the northern border of the Ouachita folded area and near the southern base of the Boston Mountains.

The length of that part of the flexure which is visible, and which at the time the photograph was taken had recently been freshly exposed in working the road, is ten feet, and the height five feet.

Aside from the interest which attaches to this as an example

of an overthrust fault passing into an anticline below, it bears strong evidence of very recent tangential pressure having been brought to bear upon the rocks of the region; for it is inconceivable that so small a flexure should break and produce a fault with many feet of superimposed rock to be broken through. The point is sufficiently elevated to suffer from slight erosion, and as the rock is mainly shale and easily eroded, the very few feet that have been removed since the faulting occurred could not represent much time, as the geologist reckons time.

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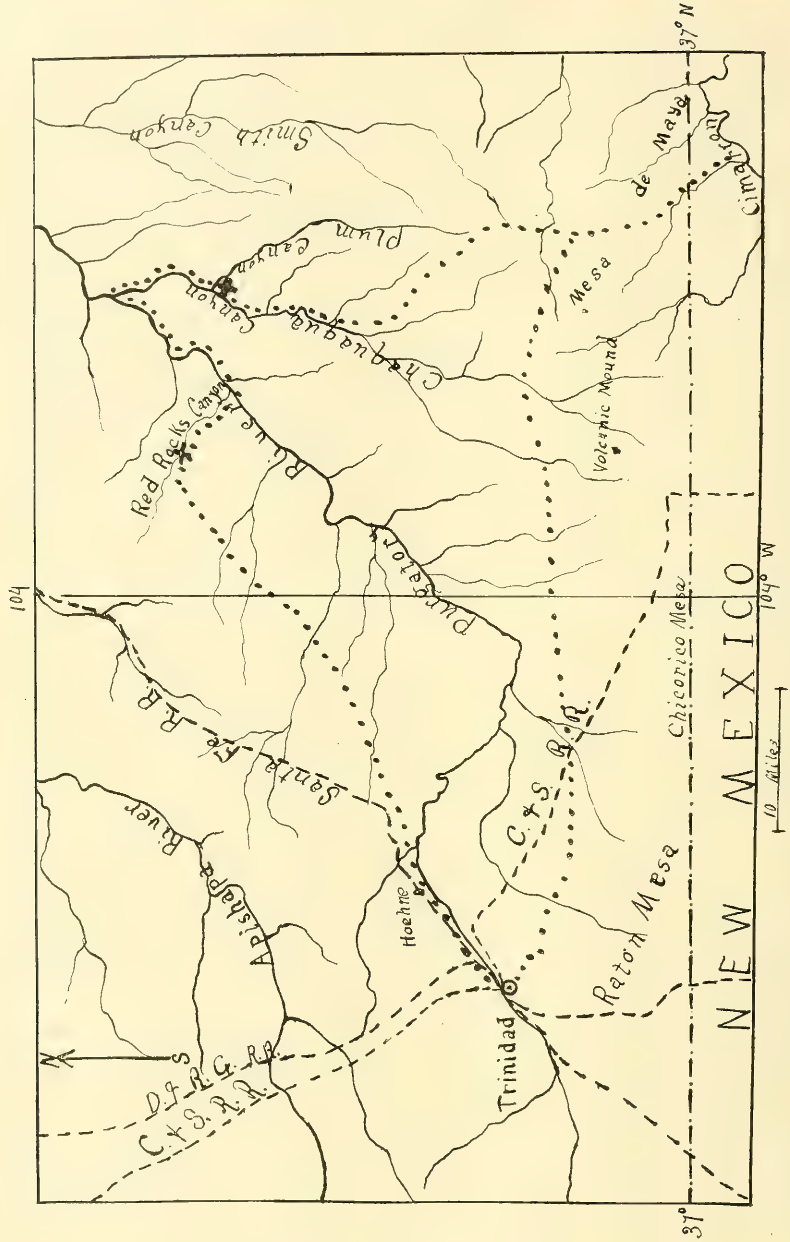
THE MORRISON FORMATION OF SOUTHEASTERN COLORADO

A considerable part of southeastern Colorado and northeastern New Mexico is elevated to a height of about 5000 feet above sea level. The streams of this region have cut canyons to the depth of 700 feet or more. The most notable of these is the canyon of the Cimarron in New Mexico, and that of the Purgatory, or Las Animas, in Colorado. The studies of which the conclusions are given in this paper, were carried on mainly in the canyon of the Purgatory and its tributaries, although a side trip was made to the canyon of the Cimarron. The region examined is shown in the accompanying sketch map (Fig. 1). The canyon walls are steep and bare and complete sections are easily obtainable. The lower half is red sandstone overlain with gypsum (the "Red Beds"); the surface rock is also sandstone (Dakota.) Between this upper sandstone and the gypsum is the shale formation of which I specially write. The shales are found throughout the region examined wherever the streams have cut through the upper sandstone.

Two detailed sections were taken at the points indicated on the map by a cross (×), section 1, at the junction of Plum and Chaquaqua canyons, and section 2, in Red Rocks Canyon. Since the canyons do not cut entirely through the Red Beds at any point within the area examined, it is impossible to accurately estimate their full thickness; the sections, therefore, represent only the upper part of these beds.

For some distance above the bottom of Plum Canyon (section 1) the rock is evenly stratified, ripple-marked and somewhat shaly. A limestone layer four feet thick near the bottom extends uninterruptedly for many miles and forms a convenient line of reference. Above these evenly stratified beds occurs a series of massive layers of coarse red sandstone aggregating about 250 feet in thickness. This series forms the steepest and

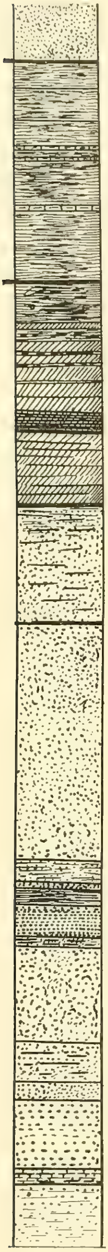

37° N
104°
104° W
37°
Smith Canyon
Plum Canyon
Canyon
Chaquaqua
Red Rocks Canyon
Purgatoire
Mesa de Maya
Cimarron
Mesa
Volcanic Mound
Chicorico Mesa
NEW MEXICO
10 Miles
Santa Fe R.R.
C. & S. R.R.
Apishapa River
Hoehne
Raton Mesa
Trinidad
D. & R. G. R.R.
C. & S. R.R.
N
S

most conspicuous part of the canyon walls. It is notably cross-bedded and the frequent changes in the direction of bedding, as well as the frequent truncations of the cross-bedded layers, is indicative of deposition by shifting currents. The upper part of the massive series is slightly calcareous and oölitic, the little spheres of which, about one millimeter in diameter, are harder than the matrix in which they are set, and the weathered surface is thus given a "bird's-eye" appearance. The oölitic beds pass gradually upward into gypsiferous shales and thence into solid gypsum without any indication of stratigraphic break or lapse of time. No trace of fossils of any kind was found in the Red Beds.

The upper sandstone forms the general surface of the country over wide areas. The Cretaceous formations from the Ft. Pierre to the Dakota are traversed in passing eastward from Trinidad across the El Moro quadrangle which has been described by R. C. Hills,[1] and the Dakota, may be traced onward thence over the whole region studied. The Dakota is composed mainly of sandstones, although shales occur in it in places. About 150 feet from the base occurs a steel-blue shale (probably fire-clay), 2 to 6 feet thick were examined. Above this clay the formation is somewhat evenly bedded, ripple-marked and in certain places contains numerous impressions of dicotyledonous leaves. In a few places small pebbles were found near the base. The largest of these were about one fourth inch in diameter. The pebbles are so few in number that the strata containing them can scarcely be described as conglomeratic.

Between the Dakota and the gypsum at the top of the Red Beds lies the shale formation under consideration. It is constant in occurrence, although the thickness varies from place to place. At the mouth of Plum Canyon the thickness is 85 feet; in Red Rocks Canyon, it is 132 feet. In Chaquaqua Canyon, ten miles from the mouth of Plum Canyon, it is 175 feet (by barometer). The formation is composed mainly of variegated clay-shales of the variety known as "joint clay." A subordinate amount of

[1] U. S. Geol. Surv., El Moro Folio, Colo.



140 feet. Dakota. Two massive sandstone layers separated by a soft shaly layer of varying thickness; leaf impressions near the top of the upper division.

11 feet Greenwich clay shale, soft and fine grained.

12 feet dull red clay shale, soft and fine grained.
10 feet brown to yellow shale.
6 inches argillaceous limestone; numerous fine dark laminæ.
18 inches buff-colored shale.
6 inches argillaceous limestone; numerous fine dark laminæ.
18 feet variegated joint clay.

2 feet argillaceous limestone, fine grained and hard, with contorted laminæ.

30 feet variegated shales; very soft and easily eroded.

15 feet dark shales containing irregular masses of gypsum.
18 inches gypsum containing streaks of clay.
8 feet variegated shale containing nodular-like masses of gypsum which vary in size from grains to masses a foot or more in diameter. About one third of the mass is gypsum.

25 feet gypsum in well-defined layers. Often separated by layers of clay.

5 feet massive gypsum.

30 to 40 feet red gypsiferous shales, soft and regularly bedded.

60 feet red calcareous sandstone, oölitic, cross-bedded. Individual layers variable in thickness and character. Near the top it becomes shaly and passes gradually into the gypsiferous shales above.

175 to 200 feet red sandstone, massive, cross-bedded.

6 feet red arenaceous shale.
1 foot red sandstone.
4 feet fine red shale.
9 feet even-bedded red sandstone.
2 feet red arenaceous shale.

40 feet red sandstone, cross-bedded; the individual layers thin out laterally.

15 feet poorly cemented red sandstone alternating with layers of shale.

5 feet massive red sandstone.

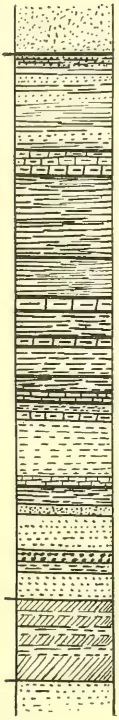
30 feet soft red sandstone containing hard layers which are ripple-marked.

4 feet hard, white, argillaceous limestone composed of numerous thin layers; greatly contorted.

15 feet red sandstone in thin flaky layers.

(River bottom.)

FIG. 2.—Section 1, near the mouth of Plum Canyon.



Dakota sandstone.

25 feet brick-red arenaceous shale, containing bands of hard, fine-grained sandstone.

3 to 5 feet reddish limestone having a conchoidal fracture and very brittle.

30 feet soft dark clay shale.

11 feet light brown clay shale.
6 inches argillaceous limestone.
7 feet brown shale.
1 foot concretionary limestone.
7 feet variegated clay shale; joint structure.
3 feet fine yellow paper shale.
6 inches argillaceous limestone, finely laminated.
18 inches fine shale.
1 foot white limestone.
15 feet variegated clay shale.
8 inches argillaceous limestone, finely laminated.
4 feet yellow shale.
1 foot sandstone containing agate either in concretionary masses half an inch or more in diameter or [disseminated generally throughout the mass.
8 feet sandstone, easily crumbling; made up of thin layers.
2 feet massive sandstone, poorly indurated.
2 feet fine paper-shale.
7 feet massive sandstone, poorly indurated.

12 to 20 feet gypsum interstratified with layers of clay.

— red sandstone (Red Beds).

FIG. 3.—Section 2, in Red Rocks Canyon.

sandstone occurs in places but there seems to be no particular horizon at which this is likely to be found. In Red Rocks Canyon it occurs at the base; in Plum Canyon, none is found; in a side gulch east of Plum Canyon a brecciated layer occurs near the top containing angular fragments one quarter inch in diameter; in Chaquaqua Canyon, four miles from the mouth of Plum Creek, a coarse cross-bedded sandstone layer 15 feet in thickness occurs about 50 feet from the top; just across the canyon from this point, perhaps two miles distant, and at the same horizon, about 30 feet of limestone is found in place of the sandstone. In many places the sandstones are friable and composed of nearly pure quartz. The sand is used as a flux in assaying where pure silica is required. The occurrence of the limestones, most of which are more or less argillaceous, is as eratic as that

of the sandstones. The relative amount and position of sandstones, shale and limestones at any one point is no indication that a similar relation will be found at any other point. There is no abrupt lateral change, but the various beds blend into each other or pinch out laterally in a gradual though somewhat rapid manner, so that, while no sudden change is seen, a comparison of sections a few miles apart may show a total change in kind and relation of materials. The Dinosaur bones to be described later were found in the shales at nearly every horizon. Aside from these, no fossils were found. Careful search at every horizon failed to reveal a single invertebrate.

The three formations—the Red Beds, the shales, and the Dakota sandstone—are apparently conformable. There seems, however, to be some indication of a break between the gypsum and the shales, and still more between the shales and the Dakota sandstone. The red sandstone, as already pointed out, passes upward through shales into the gypsum by a gradual transition. There was no evidence found, at any of the places examined in detail, of a break in deposition between the red rocks and the gypsum. At the top of the gypsum the evidence is not so satisfactory in every case. In Red Rocks Canyon the change is abrupt from gypsum to sandstone; but in Plum Canyon and elsewhere the upper layer of the gypsum beds is shale containing irregular masses of gypsum. This is overlain by the variegated shales. The gypsum beds vary in thickness from 20 to something like 100 feet. In some places, at least, as shown in the sections given in this paper, the shales increase in thickness as the gypsum decreases, and vice versa. It is possible, therefore, that the gypsum beds were exposed and slightly eroded previous to the deposition of the shales. However this may be, it seems clear that the gypsum belongs to the Red Beds series, and probably marks the closing stage of the Red Beds period. If this interpretation be correct, there is no gypsum in any part of the shale formation of southeastern Colorado, so far as known. The contact of the shales with the Dakota sandstone is more plainly marked, and in places exhibits gentle undulations,

which appear to be due to erosion of the shales previous to the deposition of the Dakota.

Vertebrate fossils were found in the shales near the mouth of Plum Canyon in a number of places. No means were at hand for digging deep enough to obtain good material, but many fragments were found on and near the surface. Two of the best preserved fragments—the centrum of a vertebra and the portion

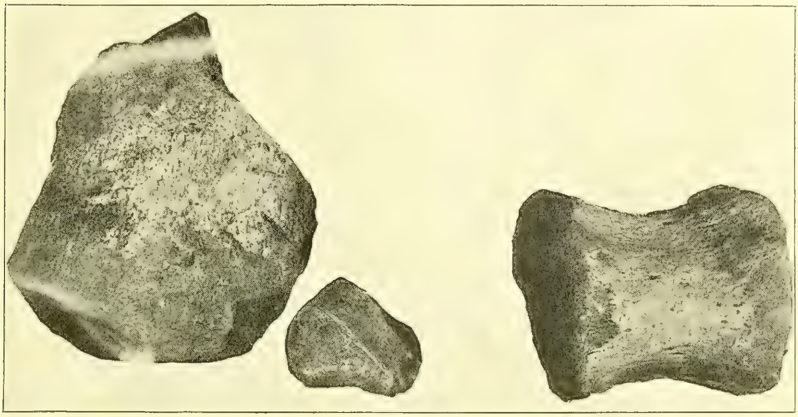


FIG. 4.

of a femur—are shown in the photograph, Fig. 4, about one eighth natural size. The dimensions of the vertebra are as follows:

Length - - - - - -	8	inches
Transverse diameter at ends - -	7	"
Depth at ends - - - - -	8	"
Transverse diameter at center - -	5¼	"
Depth at center - - - -	6½	"
Depth of sockets, each - - -	½	"

The fragment of the femur is 13 inches long, 12 inches wide, and 7 inches in diameter. This does not represent the thickness of the complete bone, since one side is imperfect. These bones are solid and coarse in texture. One hollow bone was also found. The piece is about 5 inches in diameter and 7 inches long, with a hollow 2 inches in diameter. The material obtained is not sufficient for generic determination, but in size, texture,

and general aspect the bones are similar to the Dinosaurian remains of the Atlantosaurus Beds of central Colorado and Wyoming.[1]

That portion of the general section for the Rocky Mountain region which is useful for present comparison is as follows: The Red Beds formation (the so-called Jura-Trias) is overlain by the Morrison formation, or Atlantosaurus Beds. The line of demarcation is drawn at the top of the gypsum beds which occur in several localities along the mountains at the summit of the Red Beds. The gypsum is regarded as marking the closing stage of the Red Beds period. The Morrison formation, which averages about 200 feet in thickness, is composed principally of variegated shales. These contain sandstones and impure limestones, the thickness and relative position of which vary from place to place, or may be entirely wanting. It is this formation which is noted for its huge Dinosaurs. Above the Morrison occurs the Dakota sandstone. It should be borne in mind that only the middle one of these three formations, the Morrison, contains Dinosaurian remains.

Since the vertebrate fossils of southeastern Colorado have not been studied, and since they are the only known fossils from the shale formation of that region, we must resort to other means of determining the age of the shales, and these will be chiefly stratigraphical and lithological, to which may be added such general paleontological evidence as may be drawn from unidentified bones.

a. As stated in a previous paragraph, the upper sandstone of the region in question was traced from a known area, and there can be little doubt, therefore, that it is Dakota. The Red Beds are in structure, color, and general aspect similar to the Red Beds of the mountain region, seventy-five miles to the west. They differ only in being composed of finer material and in being massive near the top instead of evenly stratified, as is often the

[1] Since writing this article my companion, Mr. T. A. Pierce, has again visited the bone beds and found a number of new localities where bones occur in considerable numbers. The width of the territory in which these remains are found and their number indicate that this region would yield rich rewards to the bone hunter.

case in the typical Red Beds along the mountains. The stratigraphic position of the shale formation is between the Dakota and the Red Beds. In this respect its position is identical with that of the Morrison.

b. In lithological character, the shale closely resembles the Morrison, which, in its typical areas[1], is composed of soft, variegated clay, containing more or less sandstone and limestone. A comparison of the shale formation with the typical Morrison of Colorado shows a striking resemblance. There is a somewhat greater proportion of clay than in the Morrison, as would naturally be expected so far from the mountain area, which was probably a part of the feeding ground at that time. A comparison of the Morrison (Como) of Wyoming reveals a still closer resemblance, if, indeed, it cannot be called identity. One who is familiar with the Morrison and has studied the shales of southeastern Colorado finds a striking likeness between the two in material structure and general aspect.

c. The Morrison is notable chiefly for the great Dinosaurs found in its beds, and they are not found in the Dakota above nor in the Red Beds beneath. The bones found in the shales near Plum Canyon are similar in size, texture, and general aspect to the characteristic Dinosaurs of the Morrison formation. Although none of these bones have yet been studied by a paleontologist, there is little doubt that they are Dinosaur bones, and if Dinosaurs occur between the Dakota and the Red Beds, the presumption is that the formation containing them is an equivalent of the Morrison.

The shales found in the Canyon of the Cimarron perhaps deserve separate discussion. Near the southern boundary of Colorado is the divide between the Cimarron and Purgatory rivers. On this divide, a distance of nearly thirty miles, no stream, so far as observed, cuts through the Dakota. At the top of this divide is an extensive mesa capped by flows of basalt and

[1]See U. S. Geol. Surv., Monograph XXVII, Geology of the Denver Basin, p. 52; also W. N. LOGAN, Kas. Univ. Quarterly, 1900—"The Stratigraphy and Invertebrate Faunas of the Jurassic Formation in the Freeze-Out Hills of Wyoming," pp. 113-115.

known as Mesa de Maya. It is a part of the volcanic region extending from the mountains eastward along the southern border of Colorado. This mesa is separated from the equally elevated region of northern New Mexico by the canyon of the Cimarron, which is cut not only through the basalt and the Dakota, but deep into the Red Beds. Here, as further north, a shale formation lies between the Red Beds and the Dakota. At the one point studied gypsum occurs near the top of the Red Beds, but a thick stratum of red sandstone lies between it and the overlying shales. The shales correspond closely in character and general appearance with those further north, although they are more arenaceous and thicker (about 350 feet). No fossils of any kind were found, but enough was seen of the formation to warrant the inference that it is probably the same as the formation which occurs in the same position in the canyon of the Purgatory, thirty miles further north, viz., the Morrison.

SUMMARY

1. From the foregoing considerations it appears that the stratigraphic, lithologic, and paleontologic evidence all point to the inference that the shales of southeastern Colorado are of Morrison age. It is inferred, furthermore, that this formation extends from its line of outcrop along the flank of the Front Range, underneath the Dakota, as far east as Smith Canyon, about seventy-five miles, and as far south as the canyon of the Cimarron. How much further it extends in these directions is not determined.

2. Although there are gypsiferous shales lying between the gypsum and the fossiliferous shales, which might seem at first thought to form a transition, it is thought that the line of demarcation should be drawn at the top of the gypsiferous shales. If this division be correct, there is no gypsum in the Morrison formation of southeastern Colorado. In this it differs from that formation as reported from some localities. The gypsum is here considered as belonging to the closing stage of the Red Beds period.

Willis T. Lee.

Trinidad, Colo.

EDITORIAL

THE JOURNAL has had occasion to comment with some severity on the action of certain former officials of the state of Missouri relative to the official geological investigations of that state. It is therefore with the greatest pleasure that it now makes note of the recent appointment of a new Board of Managers of the Bureau of Geology and Mines, by Governor A. M. Dockery. The following gentlemen have been elected officers of the Board: President, Professor E. M. Shepard, Springfield, Mo.; Vice President, Dr. E. B. Craighead; Secretary, Colonel H. H. Gregg, Joplin, Mo.; Dr. W. S. Allee, Olean, Mo. The headquarters of the survey have been removed to the School of Mines at Rolla, under orders from the legislature. A state geologist will soon be appointed.

Reviews.

Department of Geology and Natural Resources of Indiana, Twenty-fifth Annual Report. By W. S. BLATCHLEY, State Geologist, Indianapolis, Ind., 1900. Pp. 782. Maps and plates.

The current report deals mainly with the cement resources of the state. It opens with a short paper by the state geologist on Portland cement, a compilation treating of its history, uses, composition, process of manufacture, methods of testing, etc., together with a short history of the development of the industry in Indiana.

The report on the Lakes and Marl Deposits of Northern Indiana is the result of the joint work of the state geologist and and Dr. George H. Ashley. It is a thorough report of some three hundred pages and is accompanied by seventy maps of individual lakes on which the marl deposits in their varying conditions of occurrence are represented by conventional signs. In the body of the text, full physiographic descriptions of the lakes are given, as well as the detailed economic geology of the marl deposits. The notes on the natural history of these lakes, which are appended to the descriptions, are of much interest to the student of botanical ecology.

It is found that a deposit of marl of a thickness of ten feet and covering 160 acres will supply a factory of 500 barrels daily capacity for 30 years. Such a supply is termed a "workable deposit" in the report. There are thirty-two lakes which have at least that much marl available. With improved methods of raising marl from deeper waters, the productive area of these lakes will be much enlarged, and there will be added to the number half as many more, whose deposits are for the most part under water of greater depth than ten feet, the present limit of accessibility.

In regard to the origin of the marl the authors do not attribute more than 1 per cent. to shells as a source. The immediate source they believe to lie in the calcareous matter of the glacial clays which reaches the lakes in the form of the soluble double carbonate, $CaH_2(CO_3)_2$. This is believed to be carried by subterranean rather than superficial streams, because the marl deposits are found in

association with sub-lacustrine springs, while the mouths of streams and the currents leading away from them are marked by deposits of muck and silt. Calcium carbonate ($CaCO_3$) will be deposited if by any means CO_2 be withdrawn from the double carbonate. The authors recognize three such means.

1. Increase in temperature from mingling with the warmer lake waters.

2. Decrease in pressure as the spring water rises to the surface.

3. Extraction by aquatic plants, such as stoneworts, etc.

Since more than half the marl lakes do not have the stoneworts in abundance, and since the marl in general does not show that large percentage of organic matter which is shown by marls deposited through the agency of the stoneworts, the authors are inclined to minimize the part of aquatic plants.

As the spring water is colder than the lake water and denser owing to the carbonate in solution, we can see no cause for the rise of the spring water, except diffusion, in which the CO_2 released by ascending waters would be just balanced by that taken into solution by the descending currents.

If the main dependence is to be put upon the first means for removing the CO_2, *i. e.*, increase of temperature, it seems to us that springs which emerge superficially in the neighborhood of the marl lakes would have their waters warmed more rapidly than sub-lacustrine springs, and should thus have copious deposits of marl. No reference is made to such deposits. We believe a competent theory for the deposition of the marls is yet to be found.

The state is to be congratulated on the timely appearance of this report and will reap the benefits which accrue from early occupation of the field.

"The paper on the 'Silver Creek Hydraulic Limestone,' by Mr. C. E. Siebenthal, contains full details regarding the location and stratigraphy of the stone so largely used in southern Indiana for the manufacture of natural rock cement, as well as an historic, descriptive, and statistical account of the industry. It is accompanied by a map showing the exact location of the cement rock."

Of the Bedford limestone[1] there was quarried in 1900 some 7,035,000 cubic feet, with a value of $1,699,649.

[1] The article on this subject contributed to the current report by the writer, was made to read "Indiana Oolitic Limestone," without the consent or knowledge of the author.

From the report of the state mine inspector we learn that the production of coal in 1900 reached the largest figure in the history of the state, being 6,351,976 tons, valued at $4,883,024.18.

In a paper on the petroleum industry, the state geologist supplements his articles in the Twenty-first and Twenty-second reports, by noting recent developments in the main Indiana field, as well as in several smaller fields recently exploited. The paper is accompanied by a map of the field. The oil and gas reservoirs of the state are found to be mainly in the porous dolomitic upper portion of the Trenton limestone which does not appear at the surface anywhere in the state. The author conceives the dolomitization to have resulted from the concentration of sea water in the shallow indentations of the coast or marginal lakes, with resulting substitution of magnesium for calcium in the rock below. The total production of oil in 1900 was over 5,000,000 barrels, valued at about $5,000,000, one dollar per barrel.

The last paper in the report is from the pen of Dr. E. M. Kindle, and is entitled, the "Devonian Fossils and Stratigraphy of Indiana." It is one of the most important contributions which has ever been made to the knowledge of the paleontology of the state, and, with the exception of Dr. Foerste's work on the Silurian, is the only attempt which has been made to systematically explore the faunas of a group of Indiana rocks.

The first part of the paper takes up in detail the stratigraphy of the various localities, and discusses their faunal relations and correlation. The discovery at Delphi, Ind., of a new fauna in the New Albany shale leads Dr. Kindle to regard that formation as the western equivalent of both the Portage and Chemung, instead of the latter alone. Another interesting fact is that the Devonian limestones, which are well differentiated into the Sellersburg beds and the Jeffersonville limestone in the southern part of the state, give way to the dolomitic Geneva limestone and the Pendleton sandstone in the middle area, but resume their double facies again in the Wabash region, noting, however, that the Sellersburg beds hold very different faunas in the two regions.

The second part of the paper deals with the paleontology of the Devonian beds. The specific descriptions are preceded by keys for the discrimination of the species attributed to each genus, and these, taken in connection with the thirty-one excellent plates, comprising more than three hundred figures, make the paper an exceedingly useful handbook of this formation, particularly for Indiana students.

C. E. Siebenthal.

Summary Report of the Geological Survey Department [of Canada] *for the Year 1900.* Ottawa, 1901.

Among the more interesting features of the work of the year are (1) a series of experiments in separating the magnetic element from black auriferous sands by a magnetic separator, and thereby concentrating the gold in the non-magnetic residues (collected by J. C. Gwillim, treated by J. B. Porter); (2) the discovery of salt at St. Grégoire in a red formation referred to the Medina, which throws light on the conditions attending the origin of that formation in common with other red sand and marl deposits; (3) a survey by J. McAvoy of the Crows Nest coal field, which is estimated to contain over 22,000,000,000 tons of workable coal of excellent coking qualities and low percentage of ash or other deleterious substances; (4) additional discoveries of Cretaceous coal in northern British Columbia, indicating that "the coal-bearing Cretaceous rocks occupy a much larger area than had been supposed between the 55th and 57th parallels of latitude, while anthracite coals have actually been found in the region about the head-waters of the Skeena and Stikine rivers" (J. S. O'Dwyer and A. H. Dupont); (5) a further report on the Klondike district, dealing with its indurated series and its gravels, gold and copper deposits, lignites, and glaciation (R. G. McConnell); (6) the exploration by J. C. Gwillim, of the Atlin district (about 60° lat. and 134° long.); (7) additional results in the Kootenay district; (8) an outline of explorations, by J. M. Bell, about Great Bear Lake and Great Slave Lake; (9) a brief statement of work on the crystalline area northwest of Lake Superior, by William McInnes; (10) a report of work north of Lake Superior, by Robert Bell, relating especially to iron ore developments; (11) studies, by W. A. Parks, in the Muskoka district; (12) examination of the region south and east of Ottawa, by Dr. Ells; (13) studies in the vicinity of Montreal, by O. E. LeRoy; (14) the examination of Shefford Mountain, by J. A. Dresser; (15) work in the Lake St. John district, by G. A. Young; (16) work on the great slate belt of New Brunswick, by L. W. Bailey, in which fossils indicating Ordovician and Cambrian ages were found; (17) investigations on the surface geology of northwestern New Brunswick, by R. Chalmers; (18) work in Nova Scotia on the coal field, by H. Fletcher and M. H. McLeod, and on the gold field by Mr. E. R. Faribault; (19) outlines of chemical, paleontological, and natural history investigations.

The preliminary determination of the geologic series of the Atlin district is as follows:

1. Sandstones and argillites of probable Cretaceous age, in the basins of southern Taku arm and Atlin Lake, with an expected continuation to the south-east by Pike Lake, and the Nakina River.

2. The characteristic rocks of Pine Creek basin are different varieties of magnesian combinations, together with some greenstones of a diabasic character. Magnesite, serpentine, dunite, greenstone, actinolite slates and a very friable gray limestone are the chief rocks. These were not seen outside of the Pine Creek and McKee Creek basins excepting in two or three localities. They extend in patches across Atlin Lake westward into Taku inlet and possibly over towards Taku arm to a point five miles south of Toochi River. Another area of these typical rocks is found about Chehalis Creek, south of Gladys Lake, as mentioned previously.

3. Cherty quartzites and various kinds of clay-slates, together with patches of gray or black limestone distributed over the great flats west of Dawson Peaks and Gladys Lake, O'Donnel River basin, and eastwards to Teslin Lake at its southern end.

4. Great masses of crystalline limestones on northern Taku arm, Little Atlin Lake, Lower O'Donnel River, and at the junction of Silver Salmon and Nakina Rivers.

5. Late eruptive rocks of basaltic and porphyritic characters, all about the southern parts of Atlin Lake, constituting the central portions of most of the groups of mountains there.

6. Granites of the Coast Range at the south end of Taku arm, and isolated masses of granite from the northern end of Atlin Lake eastwards across Surprise Lake, and Snowdon Mountains to near Teslin Lake; also McMaster Mountains east of Lower O'Donnel River, and the bowlder-stream plateaus seventeen miles eastward, from Ruth Lake on the Taku trail.

The conclusions relating to the ages of the rocks in the Kootenay district are as follows:

The crystalline gneisses and schists are of uncertain age, probably they include rocks of different age, but they are, at all events, among the oldest rocks of the district. The Nisconlith rocks are Lower Paleozoic, supposed to be about Cambrian. The Cache Creek rocks are Upper Paleozoic, probably Carboniferous. This is the age also assigned to most of the greenstones (andesites, porphyrites, serpentines, etc.), and the limestones and argilites associated with them. Some of the andesite and agglomeratic rocks in the Trail Creek district are no doubt younger, but there is no definite information regarding their age except that they are older than the conglomerates and the Rossland granite. The gray granite which cuts the greenstones is probably

about Jurassic. The monzonite-like rocks appear to be younger than the gray granite, which would indicate that they belong to the Cretaceous.

The conglomerates are amongst the younger rocks. The Lake Mountain conglomerate is supposed by Mr. McConnell to be Tertiary. It bears a strong resemblance, both lithologically and stratigraphically, to the conglomerates associated with the Tertiary volcanics on the Kettle River, which are supposed to be of Tertiary age. The Rossland granite, which sends dykes through the conglomerates both on Sophie Mountain and on the Kettle River, is evidently younger than these. Dr. Dawson has observed granite very much like the Rossland granite, cutting the Cretaceous rocks, in the Kamloops district. The Rossland granite, again, is newer than some of the basalts, as inclusions of the latter were found in it, and reddish porphyry dykes, seemingly identical with those from this granite, were observed cutting the lower volcanic beds. There seems good ground, therefore, for supposing this granite and the accompanying porphyries to be Tertiary (R. W. Brock).

C.

Aus den Hochregionen des Kaukasus. Wanderungen Eslebnisse, Beobachtungen von GOTTFRIED MERZBACHER. Two volumes, 1920 pages, 246 illustrations from photographs, 3 maps. Leipzig: Duncker & Humblot, 1901. Price, 40 marks.

This is another great work on the Caucasus, which may be compared favorably with that by Freshfield. The two large volumes by Merzbacher deserve a more extended review than it is possible to give them at this time. They present in very attractive form the result of much labor in exploring the peaks and snowfields, the glaciers and valleys of the lofty Caucasus, as well as in study and observation of the country and its peoples. Much labor has also been bestowed upon the preparation of the book, which appears in the character of the 246 illustrations, most of which, from photographs taken by the author, have been redrawn with great success artistically, especially those by E. T. Compton. The three topographic maps of the region, on a scale of 1 : 140,000, furnish a great deal of valuable detail. A most convincing evidence of the care taken with the preparation of the book is the index of 117 double-columned pages. So also are the frequent bibliographic references.

The first chapters are devoted to the general discussion of the orography and structure of the high Caucasus; their glaciers, hydrography, passes, and subdivision into three groups, western, central, and

eastern. Then follows a comparison of these mountains with the Swiss Alps, in which the Caucasus is shown to excel in loftiness and grandeur of peaks and mountain masses, and in wildness and solitude. But the Swiss Alpine valleys surpass those of the Caucasus in the charm of their beauty and restfulness. There are chapters on the ethnology of the peoples inhabiting the region, and an historical sketch of the explorations of the mountains.

These chapters are introductory to the narrative of the explorations by Merzbachen, who, as an Alpine climber, undertook the ascent of the loftiest and most forbidding peaks. The narrative begins with his departure from Munich in 1891, and the details of the journeys are presented with such thoroughness as to constitute a veritable guide-book of the country traversed. Passing through Batum and Kutais to Tschwelieri, the mountains are entered by way of the Lahpari Pass. Following an unsuccessful attempt on Ushba, are the ascents of the Laila and the Tetnuld, the crossing of the Adur-see Pass into the Baksan Valley, the ascent of Elbrus and a series of high peaks east to Kasbek, which, with a journey to Tiflis completes the experience of the first season. The second expedition, in the summer of 1892, was directed to the eastern portion of the range, and a number of lofty peaks ascended, including Tebulos-mta, Komito tawi, and Donos-mta.

The book finishes with a chapter on the map of the mountains and a discussion of the names applied to the peaks and passes; also a petrographical description of rock specimens and fossils collected by the author and studied by Dr. Ludwig von Ammon. Finally, there is a statement of all things possibly needed for such an expedition: clothing, camp outfit and provisions, apparatus, medicines, and presents suitable for those whose favors could not be repaid with money.

J. P. I.

The Geological History of the Rivers of East Yorkshire [England]; being the Sedgwick Prize Essay for the Year 1900. By F. R. Cowper Reed, Trinity College, Cambridge.

In this study the modern physiographic mode of working out the history of topographic and drainage systems is employed with apparent success, following confessedly American precedents. The general conclusions are thought to apply to East England, and perhaps more widely. They are set forth as follows:

By the preceding examination of the geological and physical evidence we have traced the general outlines of the evolution of the present drainage system of East Yorkshire through several successive stages, and we find that its history is intimately bound up with that of the whole of Eastern England since Palæozoic times. There are local details still waiting to be filled in, and branches of the subject still to be investigated, but it is believed that they will produce no evidence which will contradict the main results here worked out. The division of the physical history of the region since Cretaceous times into six stages or cycles is based on geological evidence which is practically incontrovertible; the assumptions as to the original slope of the surface and the deformation of the peneplain are supported by orographical measurements and geotectonic considerations of great weight, as well as by being in harmony with evidence from other parts of England; and, finally, the theory of consequent and subsequent streams has been established on a firm foundation by Davis and many other workers in the same field. The hypothesis of the secondary origin of the Moorland anticlinal as a watershed more or less parallel to the original consequent streams has been found to afford a natural and satisfactory explanation of the behavior and characters of the water courses which it concerns; and the modifications effected by the glacial period have been interpreted in most cases from direct field-evidence.

T. C. C.

The Conveyance of Water in Irrigation Canals, Flumes, and Pipes. By Samuel Fortier. [Bulletin No. 22, Water Supply and Irrigation Papers, Division of Hydrography, United States Geological Survey.]

The paper calls attention to present practices in the conveyance of water in the irrigated districts in different parts of the arid West and points out ways in which works of this character may be built with greater permanence and at less cost than those now in existence. As the relation of the cost of delivering water to the value of the crop to be raised is the vital question in irrigation, this paper should be of especial value to those in anyway affected by the results of irrigation.

The report gives a comprehensive review of the various kinds of irrigation canals and ditches, discussing the faults and merits of each and dwelling on such problems of their operation as the effects of too great or too little grade, the growth of aquatic plants and their removal, the accumulation of ice in winter, and the flow of water as affected by the nature and condition of the conduits.

Considerable attention is given to the construction and serviceability of various kinds of wooden flumes, and their development from the simpler and cruder forms to the expensive but more satisfactory flumes and pipes. There is also a section devoted to the discussion of the cast iron pipes, their history in irrigation, durability and cost.

Copious illustrations and diagrams accompany the report and materially add to its value. As the extent of arid land in the United States is so vast, fully two thirds of its area, and includes some of the richest agricultural land on the globe, this information regarding the methods and growth of irrigation will be welcomed.

G. B. H.

The University Geological Survey of Kansas. Volume IV, Paleontology, Part II. By Samuel W. Williston, Paleontologist.

This part two of the paleontology of Kansas is devoted to the description of the Carboniferous invertebrates and the Cretaceous fishes.

The Carboniferous invertebrates, from the Protozoa to Pelecypoda inclusive, have been discussed for the report by Dr. J. W. Beede. All the species have been fully described, so that the report will be a valuable manual for the study of Upper Carboniferous or Coal-measure invertebrates. Not since Meek's report on the Coal-measure faunas of eastern Nebraska, published in 1872 in the final report of the U. S. Geological Survey of Nebraska, has there appeared so comprehensive a report of the faunas of this age, and the report will be of great value to all workers in Upper Carboniferous paleontology whether in Kansas or elsewhere. The paper is illustrated by twenty-two plates. The completion of the report, including the treatment of the additional classes of invertebrates, is promised for the next part of the Paleontology of Kansas to be published by the Survey.

The literature on the Cretaceous fishes of Kansas has been widely scattered in the past, much of it having been published in Germany from collections secured from Kansas for the museums of German univerities, and has been for the most part inaccessible to American students who have not had access to large libraries. In the present report the Selachians and Pycnodonts have been treated by Dr. S. W. Williston, and the Teleosts by Mr. Alban Stewart. These two papers together constitute a comprehensive report of the Kansas Cretaceous

fishes and are a valuable contribution which will be of use not only to the citizens of Kansas, but to all students of fossil fish.

S. W.

Profiles of Rivers in the United States. By HENRY GANNETT. Water-Supply and Irrigation Paper No. 44, United States Geological Survey.

This interesting and valuable publication embodies within a hundred pages the leading facts of about one hundred and fifty of the most important rivers and streams of the country, noting their length, drainage area, the location of water power in their courses, their peculiarities of flow, and the nature of their drainage basins.

The rivers selected are those which are the largest in size and bear most directly upon the varied interests of the country, such as the Connecticut, Hudson, Susquehanna, Ohio, Potomac, Mississippi, Missouri, Platte, Colorado, Sacramento, Columbia, and others. The figures for the tables showing height above sea level and fall per mile were collected from various sources; some were obtained from the report of the chief engineer of the United States army, some from railroad companies when their lines cross streams, and some from the Atlas sheets of the United States Geological Survey.

In the case of such rivers as the Connecticut, Susquehanna, Mississippi, and Colorado, where the surrounding country is, in part or whole, of peculiar physiographic interest, very excellent and vivid descriptions of its leading physical characteristics are given. The pamphlet is the result of much careful work, and is the first attempt to collect and compile this information in its present form.

G. B. H.

Yearbook of the United States Department of Agriculture for 1900. Washington, 1901.

The portions of this important volume of most interest to geologists are those which relate to soil investigation and the special papers on "Mountain Roads," by James W. Abbott; "The Selection of Materials for Macadam Roads," by Logan Waller Page; "Objects and Methods of Investigating Certain Physical Properties of Soils," by Lyman J. Briggs; and "Practical Irrigation," by C. T. Johnston and J. D. Stannard.

C.

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